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ABSTRACT

This document contains conference papers on various aspects of science education. The document includes 12 plenary speeches, 11 workshop summaries, speaker vitas, breakout groups' conclusions and recommendations, and poster abstracts. Titles and authors of speeches and workshops are: "The National Education Reform Movement" (M. S. Smith); "Science Education Standards" (B. Alberts); "Teachers: The Vision Supported" (J. Tuomi); "K-12 Science Education: A Teacher's View" (P. Moore); "Undergraduate Education and Professional Development of Science and Math Teachers" (W. E. Kirwan); "State Infrastructure Support for Science Education Reform" (A. Buccino); "Helping Teachers Change Science Instruction" (G. Consuegra); "Nothing is Too Wonderful to be True" (P. Morrison); "An Attractive Remedy: Matching Scientists with Teachers" (I. Hayes); "Scientists and Science Education Reform: Myths, Methods, and Madness" (J. Bower); "Are We Serious? What It Takes for Real Change" (L. Williams); "Challenge to Action" (J. M. Atkin); "Strategies for Building University Partnerships" (C. Thorsen); "Lessons Learned from the Mathematics Standards" (L. Rosen); "Scientist Volunteers: Doing Science with Children" (G. Kirwan); "Science for All: What Will It Take?" (P. DeBerry); "Family Science: What Is It?" (B. Whitlow); "Princeton's Science Advisors: A Neural Network" (D. Rubenstein); "Sandia Scientists Enhancing K-12 Education: How We've Done It and What We've Learned" (K. Eckelmeyer); "Successful Collaborations Between Scientists and Schools" (T. Ostwald); "Effecting Change in Elementary School Science Education" (C. Parravano); "Beauty and the Beast: Aligning National Curriculum Standards with State Graduation Requirements" (B. Linder-Scholer); and "Strategies for Standards-Based Assessment" (E. Stage). (MKR)

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SCIENTISTS,
EDUCATORS,
AND
NATIONAL
STANDARDS
ACTION
AT THE
LOCAL LEVEL

APRIL 14-15, 1994

FORUM PROCEEDINGS

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Sigma Xi, The Scientific Research Society

Scientists, Educators, and National Standards Action at the Local Level

FORUM PROCEEDINGS

April 14-15, 1994

Introductory Note:

The following papers were prepared for the Sigma Xi Forum in April 1994. In most cases, the authors submitted a slightly revised version of the presentations for publication. The style of referencing in each paper is that used by the author.

Sigma Xi, The Scientific Research Society is an interdisciplinary society founded in 1886. The mission of Sigma Xi is to honor scientific accomplishments, to encourage and enhance worldwide appreciation and support of original investigation in science and technology, and to foster a creative and dynamic interaction among science, technology, and society.

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Introduction

Kumar Patel, President of Sigma Xi

In August 1993, a small advisory committee composed of teachers and scientists met in California to begin planning Sigma Xi's science education conference. They argued about which topics were appropriate to include and which format would communicate information as well as provide opportunities for discussion and modeling new teaching strategies. Their goal was to bring together scientists, teachers, administrators, and policy makers to talk about the problems in K-12 science education and encourage productive collaborations for reform.

There was a sense of urgency underlying this important work. Students graduating from American high schools must be prepared to accept responsibilities—as informed citizens who vote on technological issues, as college students equipped to take on higher levels of learning, and as a capable and technologically sophisticated workforce. In a recent Congressional Research Service Issue Brief (Science, Engineering, and Mathematics Education, January 1994), it was reported that ". . . some believe the U.S. technological position may be threatened by the quantity and quality of science undergraduates and the scientific knowledge of those students entering other disciplines. Charges are being made that many students complete high school scientifically and technologically illiterate."

At the forum in April 1994, nearly 550 scientists and teachers came together to share information and develop a set of recommendations for future work. The papers included in this proceedings address national science education standards; concerns about the effect of current educational approaches on the future of the American economy and our workforce; federal legislation to overcome barriers to improve science education; the teacher's view from the classroom; as well as many local, innovative strategies to engage and excite students. The discussion groups, which met on the second day of the forum, arrived at a set of far-reaching conclusions about issues to be addressed in science education reform and suggested some ambitious recommendations for next steps.

There was no silver bullet proposed. The process of reformation will be slow, but educators and scientists now seem willing to make a long term commitment to change the way science is taught. There is less talk of blame, and more talk of working together to make a difference. There is a greater understanding that education reform is complex and requires collaboration among teachers and scientists as well as parents, community leaders, and others. Science education standards, still in the process of being developed by various groups, will play an important role in guiding reform efforts.

Although there is clearly a lot of work to be done to achieve the national goal of making American students first in the world in science and math, there is also a great deal of enthusiasm and hope. The articles included in this proceedings volume, as well as the conclusions and recommendations developed by the forum participants, are unabashedly optimistic. Working in the often difficult realm of K-12 science education reform, one can find comfort in Pogo's stouthearted declaration: "We are surrounded by insurmountable opportunities."

The National Education Reform Movement

Marshall S. Smith

This year, legislation called the Goals 2000 Act was passed, marking the first time the federal government has become directly involved in helping to improve the quality and equality of the entire K-12 education system. Before this legislation, the federal focus has been on particular target groups, such as the poor or the limited English speaking, or on particular subject matter areas, such as vocational education or mathematics.

Goals 2000 is designed to stimulate standards-based reform in all of the Union's fifty states. This legislation incorporates a strategy that is deliberately different from other federal endeavors. It is not a top-down approach filled with mandates. The emphasis is on fostering bottom-up local reform guided by challenging standards. We hope to help create a long term, productive partnership among local schools, districts, states, and the federal government focused on bringing all students to far higher levels of achievement than in the past. These are big hopes, but we are addressing a big problem. The challenges we all confront are enormous.

America prepares to enter the 21st century with a choice: We can base our prosperity on high-skill, high-technology work, or drift toward an economy of low-skill, low-wage service jobs. We know, of course, that improving education will not by itself create high-tech jobs. But if we do not ensure that all of our students are mathematically and scientifically literate, we run the substantial risk that the high-tech jobs that are created will go elsewhere. We cannot stimulate economic opportunity in the 21st century if our work force is barely prepared to face the middle of the 20th.

Perhaps of even greater importance is the stability and strength of our always fragile democracy. Few times in the past have we been as challenged by conditions of increasing inequality and widespread despair among significant segments of our society. The long term key to this problem lies with us and all of our colleagues responsible for educational quality and opportunity. A central principle that guides this administration's educational agenda has been well captured by the National Council of Teachers of Mathematics which says that "the image of a society in which a few have mathematical knowledge needed for the control of economic and scientific development is not consistent with the values of a *just democratic system* or with its economic needs."[1] The National Science Teachers Association echoes this as they call for "science for all, regardless of background, future aspirations, or prior interest in science."[2]

Yet high quality mathematics and science education is nowhere near a reality for all in America. Indeed, there remains a lot of work in both establishing challenging, high quality standards for what students should learn in math and science and institutionalizing those standards into the curriculum and training offered to students and their teachers. By and large such high quality, challenging standards have not been part of American education, except in a relatively few elite schools and for special courses such as the Advanced Placement courses. Our measures of quality have typically come from norm-referenced data rather than from external standards based on professional judgments of quality or the achievement of students outside of our system.

Moreover, evidence indicates that a substantial gap in learning opportunities and achievement remains between high and low poverty students, as well as between minorities and non-minorities. Unless attention is placed on both meeting challenging standards and providing opportunities to assist *all* students to meet high standards, this gap will continue to grow.

The task of improving quality and equality exists at all levels of the educational system and even before children enter formal schooling. Indeed, what young child does not exhibit an excitement for learning and a natural curiosity to become more knowledgeable about the world around them? When this curiosity is nurtured and supported, it can spark a love of learning that provides the best foundation for academic work.

The Carnegie Corporation report, *Starting Points*,[3] in April 1994, reminds us of the young child's need for stimulation, love, nurturance, and predictability. It also reminds us how far we have to go as a society to meet these needs. It tells us of the lack of developmentally appropriate, high quality preschool programs. Unfortunately, not all children have the opportunity to participate in preschool; especially children from low income families, who may stand to benefit the most from these programs. Less than half of preschool-age children from families with income of $30,000 or less attend preschool, compared with more than three-fourths of children in the higher income group.[4]

Once children enter elementary school, they face the same dual problems of a lack of overall quality and of disparities in educational opportunity associated with race and social class. Too few elementary school teachers feel comfortable with their knowledge and pedagogical skills in science and in mathematics that go beyond algorithmic and routine arithmetic. Thus it should come as no surprise that in many elementary schools there is little science instruction and a lot of drill and practice arithmetic instruction.[5] This is not the fault of these teachers. They, along with most of the public, have generally not been exposed to coherent instruction or creative pedagogy in science at the K-12 or college level. It is unlikely that their mathematics training emphasized the kinds of deep understanding and problem-solving experiences now expected by, for example, the NCTM student standards for mathematics. Without those experiences and knowledge, without internalized and challenging standards, there is little opportunity for them to change.

The conditions are even more dire for many minority children and children attending high poverty schools. All too often, disadvantaged students are tracked into a watered-down curriculum with a heavy reliance on isolated basic skills and "drill and kill" worksheets, at the expense of more interesting and motivating work—approaches that woefully underestimate what these students are capable of doing.[6] Indeed, developments in cognitive research--which are often applied in gifted and talented programs—demonstrate that learning need not progress in lock-step fashion from basic skills to more advanced skills.[7] Children are able to learn more complex skills before mastering the basics, and basics are more effectively taught in a meaningful and engaging context. The literature is full of "existence proofs" demonstrating that children otherwise expected to perform at low levels can attain high levels of achievement when given the opportunity and time.

Opportunities for teaching to high standards are also less available in high poverty schools. *Prospects*, the report of our national longitudinal study on education, has shown that high poverty schools have fewer resources available to provide students with a challenging educational environment than low poverty schools. This is true at the most basic level: third and seventh grade math teachers in high poverty schools are nearly 60 percent less likely to report that they have adequate supplies of basic, inexpensive materials such as pencils and paper.[8] Especially at the elementary level, math teachers in high poverty schools are more likely to report inadequate supplies of many critical instructional resources.[9] And in terms of human resources, teachers receive precious little professional development in both high and low poverty schools, with those in high poverty middle and junior high schools receiving the least.[10]

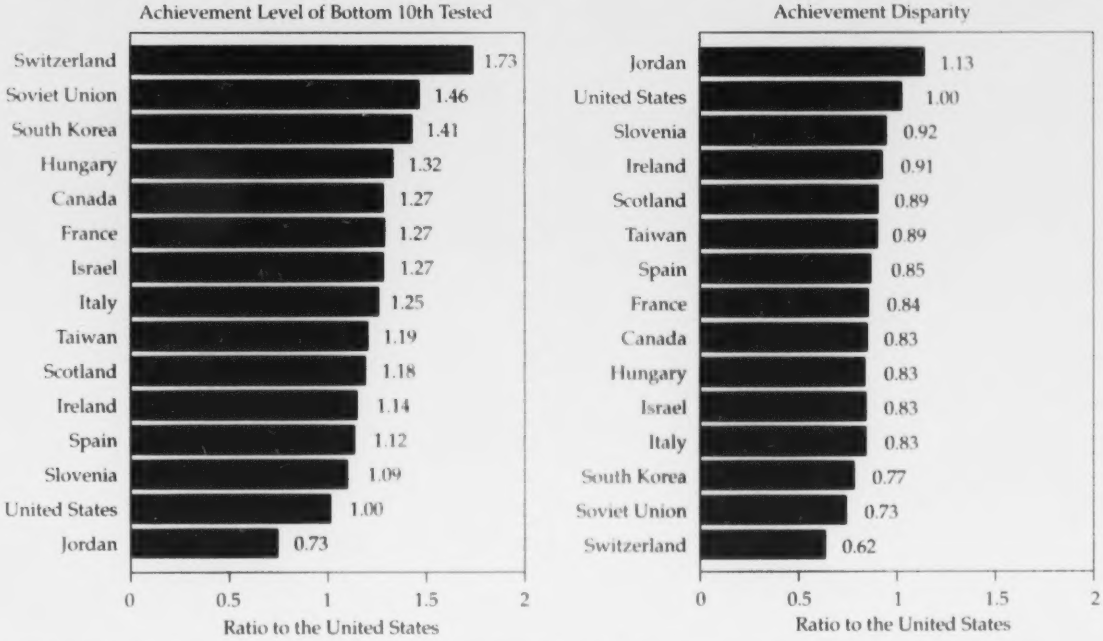
The twin problems of lack of quality and lack of equality are borne out in achievement data as well. The only national trend data that I have any confidence in come from the National Assessment of Educational Progress (NAEP). For mathematics and reading achievement, a graph of these data show a relatively flat line—generally, math and reading national achievement levels have neither fallen nor improved over the past two decades. For science there seems to have been a slight decline, at least for seventeen-year-olds, during the same time period.[11]

Level achievement over the past twenty years might be seen by some as cause for celebration. After all, schools today are tougher places to teach and learn in, and our student bodies are far more diverse. Most of us, however, believe that maintaining ground is not enough. The challenges both of the economy and of our democracy demand that our schools improve rather than just stay even. Indeed, when comparisons are made to a priori established performance standards the results are dismal.

For example, fewer than 10 percent of twelfth grade students in 1990 reached an advanced level of science achievement at which they demonstrate the knowledge required to integrate scientific information and draw conclusions.[12] In math only 2 percent of high school seniors attained an advanced level on the 1992 NAEP assessment, demonstrating that they could apply their knowledge of algebra, geometry, and statistics to solve problems in more advanced areas of continuous and discrete mathematics.[13]

On the side of equality, the story is a little different. Here, limited learning opportunities for high poverty and minority students clearly result in differences in achievement among disadvantaged children and their peers. The NAEP has found most recently that the gap in learning has begun to widen between the performance of African American and Hispanic American students and that of white students. This comes after a period in the 1970s and 1980s in which the learning gap in mathematics and reading achievement closed by about one-third, showing that we *can* close the gap. Data from 1990 to 1992 show that this gap may be widening again as the average math proficiency increased for white students at all three grades tested—fourth, eighth, and twelfth. In contrast, the only statistically significant gains in average math proficiency for minorities were for African American and Hispanic American twelfth graders.[14]

For students in high poverty communities, the picture is even



Not only is the math performance of our poor performing 13-year-olds among the lowest but the difference between the bottom 10th and the top 10th is wider in the United States than in most other countries.

Note: Achievement disparity computed as the range between the bottom 10th and top 10th, divided by the average.

Source: International Assessment of Educational Progress (Educational Testing Service, 1992)

Figure 1

bleaker. There was a narrowing of the gap between 1970 and 1988.[15] But from 1990 to 1992, average mathematics proficiency of eighth grade students in disadvantaged urban areas actually declined.[16] In 1990, against a performance standard, NAEP scores showed that 58 percent of the disadvantaged urban students failed to achieve scores at the Basic level. The proportion grew to 72 percent in 1992. *Virtually no disadvantaged urban students reached the Advanced level.*[17]

These differences are also borne out in international comparisons. From the 1991 International Assessment of Educational Progress in nine countries, we know that students in the United States perform relatively well in science and math at age nine. Yet, by age thirteen, U.S. students' performance falls far behind that of students from other countries. Thirteen-year-olds in the U.S. ranked near the bottom in both math[18] and science.[19]

International data also show that the United States provides a less equitable math education than other nations. Not only do other countries outperform us, they also show less disparity in achievement between their high and low performers *(Figure 1).*

In many other countries, the scores suggest that almost everybody gets a fairly good math and science education. In the United States, by contrast, the difference between our top 10 percent and our bottom 10 percent is very wide. So it's not that we have sacrificed excellence for equity in math education; rather, we have neither equity nor excellence. I acknowledge that interpreting international comparison data is tricky, and conclusions should be drawn skeptically, but, taken together with other evidence, I find charts such as this compelling.

Given the picture that I just described, it should come as no surprise that differences in educational opportunity and achievement at the elementary and secondary levels continue to be replicated at the post-secondary level. Even students who successfully complete high school may still have problems in college. Most of our colleges engage in serious remediation efforts for their first and second year students. And the differences between rich and poor and white and minority are reproduced here. Overall, the rate of minority student enrollment in college is about the same today as it was in the early 1970s,[20] and the gap between white and minority enrollment rates for high school graduates is the same as it was twenty years ago.[21]

African American students make up 12 percent of the American children enrolled in public schools, yet earn only 6 percent of baccalaureate degrees. They receive only 3 percent of all doctoral

Education Reform: K-12 Initiatives

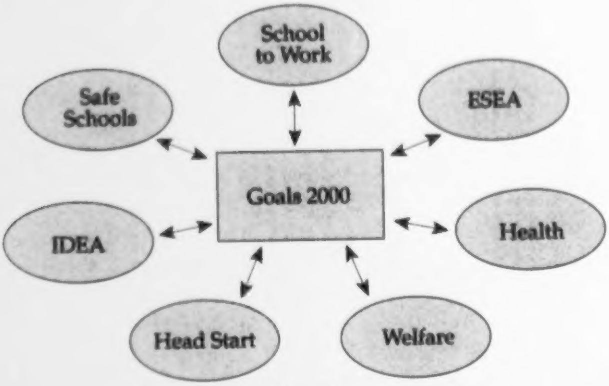


Figure 2

degrees awarded, and earn less than 1 percent of all doctoral degrees in engineering and mathematics. They also constitute less than half a percent of all full-time engineering faculty in colleges and universities. The figures for the Hispanic American community are similarly disturbing.[22]

The point of all this is that our problem is not focused just on one level or on one part of the system. It permeates all of our institutions at the preschool, K-12, and post-secondary levels. And it is not just focused on one aspect of the system, we need to pay attention to all aspects—to our standards and expectations, to the quality of our teachers and their preparation, to curriculum and assessment, and so on.

President Clinton's recognition of this issue is what guides the Administration's comprehensive agenda to support learning for students of all ages *(Figure 2).*

Beginning at birth *(Figure 3),* the President's health care and welfare reform initiatives will help to ensure that mothers receive adequate prenatal care, and lessen the incidence of low birth weight babies who are at higher risk of having learning disabilities. These initiatives will also help to ensure that children receive adequate nutrition and health care to support their development. Moreover, the President's priority for expanding and improving Head Start should give children of low-income families a greater opportunity to enter school prepared to learn.

This comprehensive package to support learning also extends beyond the elementary and secondary grades and includes appro-

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priate training for the workplaces of the future through the School-to-Work Act and increased opportunities for college enrollment through reforms in higher education. This agenda is not a fantasy—it is rapidly being enacted.

For our discussion, however, I will focus on the two initiatives that have most relevance to increasing opportunities for students to reach higher standards in mathematics and science at the K-12 level: Goals 2000 and the Administration's proposal for reauthorizing the Elementary and Secondary Education Act.

Goals 2000

At the centerpiece of the President's education reform agenda is the recently enacted Goals 2000 legislation. This act has two critical parts. The first establishes a mechanism for assessing and certifying voluntary national content and performance standards. The second part of the Act is designed to stimulate reform of the entire

The Clinton Administration's Lifelong Learning Agenda

Policy	Projected Results
School Preparedness	**All kids healthy and ready to learn**
Head Start & WIC	All eligible children receive quality services
Parent Education	Make learning intergenerational
Immunization	Immunize all children
School Reform	**More learning per dollar/meet GOALS**
Goals 2000	High standards for all students
ESEA Reforms	Improve performance through systemic reform Incentives to change • Target Chapter 1 funds • More local flexibility & accountability
School to Work	Systemic change for voc. ed., tech prep, etc. • Workplace-based and classroom learning • Nationally recognized credential
Learning for Everyone	**Future workers have the skills to compete**
College Aid Reform	New payment options, reduced overhead cost Crackdown on poor education providers Simplify programs, increase accountability Easier and earlier access to training

Figure 3

education system by providing resources for the development at the state and local levels of systemic educational reforms based on challenging *state* standards.

While some fear that "high standards for all students" will be unfair to children who are furthest from meeting them, the evidence that I just illustrated shows that these are the very children that need them most. A recent longitudinal study compared the actual achievement of students in high and low poverty schools with the grades they received. The researchers found that, when measured against the same test, a seventh grade A student in a high poverty school would be about a C student in a low poverty school.[23] We are cheating our children out of a chance to improve and build for the future. We can no longer tolerate two curricula—one for the poor and minority students and the other for the well-to-do. Without common standards and expectations and opportunity, this deceit will continue.

This situation is even more intolerable because we have evidence that all students are capable of rising to meet the challenge of high standards. Two decades of cognitive science research, both in the United States and abroad, show us that students who are expected to achieve high standards can do so when given the opportunity.[24] High standards linked to real opportunity to learn are essential to advancing our mission of ensuring equity and excellence.

What do I mean by "challenging standards"? I have talked about content and performance standards—the first sets out our expectations for what our students should know and be able to do; the second sets out markers for how well they succeed in learning this content. The Advanced Placement syllabi and examinations are one example of both content and performance standards. A better illustration of content standards for our purpose is the National Council of Teachers of Mathematics (NCTM) content standards for grades K-12 *(Figure 4)*.

The NCTM effort has demonstrated the crucial importance of voluntary standards in leading the way toward educational reform. Since they were published a few years ago, state after state has moved toward developing their own content standards using the NCTM standards to guide and instruct their work. Moreover, many states and local education agencies have begun providing professional development for classroom teachers to learn about the new standards and best teaching practices. States are taking a critical look at how they prepare new teachers and how standards can be infused into the teacher certification process. And states are

NCTM Math Standards Examples for Geometry

By the end of 4th grade, students should be able to:

Describe, model, draw, and classify shapes

Investigate and predict the results of combining, subdividing, and changing shapes

Relate geometric ideas to number and measurement ideas

By the end of 8th grade, students should be able to:

Identify, describe, compare, and classify geometric figures

Explore transformations of geometric figures

Represent and solve problems using geometric models

By the end of 12th grade, students should be able to:

Represent problem situations with geometric models, and apply properties of figures

Deduce properties of, and relationships between, figures from given assumptions

Deduce properties of figures using transformations and coordinates

Figure 4

developing new assessment tools to gauge student progress in reaching the standards.

Moreover, independent publishers have begun to gear their textbooks and assessment instruments to the guidance of the NCTM standards. Finally, the National Board for Professional Teaching Standards is designing its assessments for certification in mathematics generally around the NCTM student content standards. In short, in many states and communities, both the public and private parts of the educational system are beginning to align their most important elements, albeit loosely, around the NCTM's challenging content standards.

Some preliminary data indicate that it is working. One way to read the new NAEP data that indicate that scores for white and suburban students are increasing is that schools in more advantaged communities are adopting more rigorous standards. Without support for systemwide improvement and targeted assistance, disadvantaged communities and their students may be left behind. But, even in these communities, there are inklings of evidence to suggest that instruction may be changing. Preliminary teacher observations by David Cohen and his graduate students at the University of Michigan suggest that some teachers in high poverty schools are modifying the content and pedagogy of their instruction.[25]

In science, working groups are now developing voluntary national standards for content teaching, and assessment. The Department of Education has made a grant to the National Research Council of the National Academy of Sciences to develop content standards for what students should learn from kindergarten through twelfth grade. The project has involved classroom teachers and other educators, scientists, and the general public. By the end of this year, the National Research Council expects to complete the content standards and, in collaboration with separate working groups funded by a coalition of federal agencies, release the content standards in conjunction with standards for teaching and assessment in science.

Major national projects in science provide breadth and support for the NRC effort. These projects, such as the National Science Teachers Association's (NSTA) Scope, Sequence, and Coordination project and the American Association for the Advancement of Science's (AAAS's) Project 2061, started well before the NRC standards effort. In undertaking their effort, AAAS has provided important guidance for local and state educators as they examine ways of improving teaching and learning in their schools.

Curriculum must be changed to reduce the sheer amount of material covered; to weaken or eliminate rigid subject-matter boundaries; to pay more attention to the connections among science, mathematics, and technology; to present the scientific endeavor as a social enterprise that strongly influences—and is influenced by—human thought and action; and to foster scientific ways of thinking.[26]

The efforts of NCTM, NSTA, AAAS, and others are leading the way for the rest of the nation in developing voluntary national standards to guide education reform. The U.S. Department of Education is supporting and disseminating these standard-setting efforts. For example, under the Eisenhower Mathematics and Science Education Program, the U.S. Department of Education has awarded grants to 15 states and the District of Columbia to support their efforts to develop their own state content standards in math and science, based generally on the challenging, voluntary nationally recognized standards.

The department also has funded ten regional consortia to provide technical assistance to help states adopt and implement world-class standards in math and science, to disseminate exemplary math and science instructional materials, teaching methods, and assessment tools, and to help train administrators and classroom teachers to use them.

In short, this reform begins with the development of challenging, voluntary national standards—benchmarks of excellence, if you will, that define what students should know and be able to do. Building on this foundation and their own creativity, states are developing their own state standards and aligning their resources to provide the support needed for their students to achieve these standards.

A second key component of Goals 2000 is that it's designed to foster and support the reforms started by the professional associations' efforts. What we need is systemic reform, not disconnected efforts, however laudatory. Goals 2000 will provide support for systemic reform in every state by helping schools, communities, and states align the core elements of schooling, so that everything is working together as a coordinated system to move all children toward high standards.

At the state level, the resources will be used to design and develop state content and performance standards, student assessments and teacher professional development activities aligned with the standards, a coherent technical assistance strategy, and an accountability system focused on determining whether students have the opportunity to learn to the standards. Most important, perhaps, the state resources will be used to engage and mobilize people throughout the state—parents, business people, and educators, all concerned parties—to support the improvement of teaching and learning.

The bulk of money from Goals 2000 goes to individual schools, where the hardest work must be done. It will support school and district efforts to:

- Develop and adapt curricula to help all students reach their high standards;
- Create a variety of instructional materials, tasks, and activities that can move their children toward their high standards;
- Identify or develop within-school assessments to measure how well schools and students are advancing toward their high standards;
- Offer professional development, pre-service training, and certification for teachers, all tied to their high standards;
- Engage parents and the community in helping children reach the standards;
- Use technology to help students, teachers, and schools move toward their standards.

Goals 2000 will build on the National Science Foundation's

(NSF's) Statewide Systemic Initiatives (SSI) Program, which is a precursor for mathematics and science to the reforms envisioned in Goals 2000. With support from SSI, twenty-five states plus Puerto Rico are developing standards and assessment policies in math, science, engineering, and technology education. With the SSI resources these states have started the process of serious systemic reform in two subject matter areas. Goals 2000 will provide greater resources to bring the reforms down to the local level and will extend them to the entire range of academic subjects.

Reauthorization of Elementary and Secondary Education Act (ESEA)

I have emphasized throughout that it is not enough just to set standards. Education reform must start with standards, but it must involve more than that. Work must be done at the federal, state, and local levels to provide the support needed to ensure opportunity to learn for all students. Goals 2000 provides incentives and some resources for *states* to get involved in systemic reform and to make improvement systemwide. The federal government must ensure that federal programs pull in the same direction, aligned with the reform efforts of states and local school systems.

That's where the Elementary and Secondary Education Act, or ESEA, comes in *(Figure 5)*. President Clinton's proposal for reauthorizing ESEA, which is spelled out in the "Improving America's School Act," would refocus $10.5 billion of federal programs to support the state reform efforts in teaching and learning needed to enable all students to reach high standards. Four key priorities of this wide-ranging piece of legislation will support the opportunity of every child to learn.

First is a radical transformation in the largest of the ESEA programs, Chapter 1, into the new Title I. We recognize that setting high standards without providing the opportunity to reach high standards is a cruel charade. Low income communities must have additional help to align teaching and learning with the same high standards expected of all children. Our proposal intends to do this through schoolwide change tied to the same standards developed in the Goals 2000 reforms — flexibility at the local level in tandem with clear accountability, and more focused targeting of resources. Under a reauthorized Title I, with its $7 billion annual budget, we would encourage

Priorities of ESEA

- **Opportunity to learn**
- **Professional development**
- **Safe and drug-free schools**
- **Research and innovation**

Figure 5

many more high poverty schools to transform their entire instructional program toward enabling students to attain high standards.

While Title I services have traditionally been offered in math and reading, this proposal to expand schoolwide projects will promote the use of Title I funds in all core academic subjects, including science as well as math. In addition, Title I would align the curriculum and assessment with high state standards by using the same state assessment used for all children to measure progress. Finally, and politically the most difficult, Title I would target more dollars to the lowest income schools and districts to meet the needs of our most vulnerable students.

Our second priority, support for high quality, ongoing professional development, is key to transforming schools and classrooms into places where all students reach high standards. A new Title II of ESEA will provide the opportunity for teachers, principals, and other school staff to learn new content and new ways of engaging students in learning challenging curricula that are based on the new state standards.

What we will expect students to learn in schools by the year 2000 will be taught by the teaching force of today. While upgrading the quality of pre-service preparation for future teachers is important, development of today's instructional staff is critical. Implementing states' new standards means using new approaches to teaching. And using new approaches to teaching means that we need to foster continual new learning among teachers through professional development.

Professional development funded by this Act could focus on statewide networks of teachers or on training provided during the summer by a university or nearby laboratory to ensure that teachers in different subjects and grade levels could work together to provide an integrated curriculum. It could involve a coalition of schools, colleges and universities all working during the school year toward the common goal of improving teaching and learning in the schools. The critical factors are that the classroom teachers have a say in the design of their professional development and the content of the training stays focused on supporting all students to achieve to the standards.

We are proposing to consolidate the current Chapter 2 and Eisenhower programs into a new Eisenhower Professional Development Program. This proposal, including additional funding that we are requesting, would generate more than $1 billion for professional development each year—more than four times the annual investment under the current Eisenhower program.

High quality, ongoing professional development is absolutely key to our agenda for education reform, and not just in math and science. Our kids can't achieve high standards without the support and encouragement of well-prepared, caring teachers.

The third major priority in ESEA is support for safe and drug-free schools, creating environments where teachers can teach and students can learn. The Safe and Drug-Free Schools and Communities Act would expand authorized activities to include violence prevention and would encourage comprehensive approaches to rid schools and communities of drugs and violence.

Fourth, ESEA would support expanded opportunities for research, development, and dissemination of innovative strategies. For example, Title I will support demonstrations focused on the most innovative approaches for improving teaching and learning in schools that serve disadvantaged students. The technology program in Title III is designed to expand opportunities for learning through the improved use of technology. Technology is a powerful tool to help students achieve high standards and increase student motivation, but too often, teachers don't have enough experience with the technology to use it to its fullest potential. For this reason, we are proposing competitive grants to states, school districts, and technical assistance providers to help improve technology service at the school level. Our legislation also supports demonstrations of Charter Schools and an innovative waiver approach to be undertaken in six states.

Conclusion

Our agenda is based on the firm belief that all children can reach high standards if given the opportunity to learn. The agenda for education reform that I have sketched out for you is an attempt to stimulate efforts to reach that goal throughout our entire educational system. This is an ambitious agenda. I think of our effort as fifty exciting, long term experiments. Even in the best of worlds, fulfilling the reforms will take decades.

Ultimately, the success of this reform agenda depends on concerned citizens with different perspectives and points of view working together. That includes parents, teachers, school administrators, businesses, colleges and universities, government officials, and professional organizations. We need scientists and teachers to play a role in shaping our reform agenda, to help set standards, to teach and mentor children, and to lend support to schools. We have a practical need for this to keep our economy strong. And we have a moral need to create and maintain a just and democratic society that values the potential of each and every child.

Appendix: Examples of standard-setting at the state level

Delaware

Delaware has undertaken a massive, standard-based reform effort called "New Directions for Education in Delaware," part of which involves developing science and math frameworks. However, Delaware has gone beyond simply prescribing content standards to include student performance, student behavior, and teacher behavior standards. It is also developing new assessment tools to determine how well students master the world-class content standards they are working to achieve. The assessments are piloted at schools and revised on an on-going basis.

Standards for Delaware teachers include increased course content requirements for elementary teachers and increased pedagogical standards for secondary level teachers. Delaware students are expected to be active learners, and to learn how to succeed in group activities. The Delaware Department of Public Instruction employees say this is the reform that will take Delaware through the 90s—that it's a long-term reassessment of the education system. Delaware is looking at the basic questions about developing standards: What is good curriculum? What is good instruction? What is good assessment? How do we know?[27]

Kentucky

Following the 1989 court decision declaring Kentucky's educational system unconstitutional, the state has embarked on an effort toward comprehensive education reform. The Kentucky Education Reform Act sets forth performance-based outcomes for all students to be achieved by 1996. Part of these performance-based outcomes include a curriculum framework for math and science, including activities such as math portfolios and writing about mathematics. Thus far, the state has approved the Kentucky learner goals and standards and disseminated them to school districts.

California

California has adopted a new state vision for math and science, including state performance standards to assess how well California students meet these math and science goals. At this point, California is adopting instructional materials that meet the state vision for learning standards. California also recognizes the importance of professional development—bringing entire faculties together to network on ideas for teaching to high standards—and recognizes these professional development networks as the "engines of reform" for the educational system.[28]

The National Science Foundation-sponsored Statewide Systemic Initiatives program in California—the California Advocacy for Mathematics and Science (CAMS)—is designed around a partnership of professionals in both the public and private sectors. This effort is to address and remove barriers to the improvement of K-6 science and middle grades mathematics programs throughout the state, with special emphasis on historically underrepresented groups. CAMS's key components are a curriculum strategy to enhance professional development in science and math and a public outreach campaign aimed especially at California's Spanish-speaking community.[29]

Other good examples

- EQUITY 2000 is helping to close the gap by preparing minority students for college. Established by the College Board in 1990, EQUITY 2000 takes a systemic approach to educational reform for children in kindergarten through 12th grade. Prince George's County, Maryland, for example, has overhauled its entire math curriculum by incorporating pre-algebraic concepts from kindergarten, algebra preparation for all eighth grade students, algebra I for all ninth grade students, and geometry for all tenth grade students. EQUITY 2000 already is reaching nearly 500,000 students in more than 700 schools in six major school systems.
- The Accelerated Learning Laboratory School in Worcester, Massachusetts, connects theme-based curricula to high academic standards for *all* students. Students from kindergarten through eighth grade learn to solve problems and apply educational skills to the real world. For example, students in third, fourth, and fifth grades took a simulated 10,000-mile bicycle trek. Students got to talk by phone with adventurers who had actually made the trip. The students then took turns pedaling on stationary bikes—all the while learning to calculate time, rate, and distance, and plotting their course on a map they had created.
- The Oakland Health and Bioscience Academy arose because CEOs from Oakland's hospitals expressed their need for high school graduates who were prepared to enter health careers. Expectations for Oakland's students were low. Few of them met University of California admission requirements. Few went to college. The average graduate of the city's six comprehensive high schools earned what amounted to an eighth grade education. The worst of the six schools was Oakland Technical High School.

Today, 170 students attend the Oakland Health & Bioscience Academy, a three-year school within Oakland Tech High School, to prepare for post-secondary education and for skilled jobs in hospitals and laboratories. At least half these students go on to four-year colleges, many earning college credits in anatomy and physiology courses that are offered after school. The Academy provides added support through mentoring, field trips, guest speakers, paid internships for students, and help with applications for jobs and college.

- The Family Math program, founded in Berkeley, California, is assisting families by transforming student and parent attitudes and skills in mathematics. Through the Family Math program, families are taught non-threatening ways, like math-based games, to work together to master basic mathematical concepts at home. Family Math includes special programs targeted on minority and limited-English proficient families. Programs like Family Math help young children prepare for school by introducing them to math concepts in a positive way and by developing their self-confidence in math at an early age.[30]

- The Brooklyn Children's Museum in New York is demonstrating that learning outside the classroom can be a lot of fun through its community outreach program for at-risk youth called "Kids Crew." The after-school, weekend, and summer programs are designed to enhance literacy and cultural education, as well as to give students an opportunity to experience youth mentoring. Kids are encouraged to attend the museum at other times too, even without the company of their parents.

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Science Education Standards

Bruce Alberts

I am here this morning to give you my perspectives on science education. I would like to do this in the context of the National Science Education Standards that are being developed at the National Research Council. As you may know, the President of the National Academy of Sciences also serves as the Chairman of the National Research Council. In fact, this is what takes up 90 percent of my time.

Many of you may be wondering: What is the National Research Council? Figure 1 shows a photograph of a popular tourist attraction in Washington, the Einstein statue. It is located on Constitution Avenue, just across from the Vietnam Memorial. The building behind the statue is a mystery to most tourists.... but it is the main building of the National Academy of Sciences. This building houses many activities that have affected everyone's lives, because it is one of three in Washington that is home to the National Research Council and its 1,100 staff members. These individuals direct the activities of some 7,000 volunteers who at any one time are serving on about 650 committees.

As is true for any organization of this size, we are divided into program units, or departments. For example, there is the Commission on Life Sciences, the Commission on Geosciences, Environment, and Resources, and the Coordinating Council on Education. Each of these units is staffed by a group of individuals who have expertise in a particular program area. In the Commission on Life Sciences, for example, the staff includes people with Ph.D. degrees in ecology, radiation biology, veterinary medicine, and so on—as well as other people with degrees in science policy and extensive experience in government.

I first became involved with the National Research Council when I was asked to chair the Committee on Mapping and Sequencing the Human Genome, in the Commission of Life Sciences. Our study took fourteen months to complete, and it set out a plan for a human genome project that was largely adopted by the government. I view our committee's experience as typical for the National Research Council.

Each committee consists of a diverse group of experts, and the role of the committees is generally to reach a conclusion that is

Figure 1

based on detailed study and intimate contact with the entire spectrum of individuals on the front lines. In my case, the individuals on the front lines were laboratory scientists, but in other cases, they have been outstanding school teachers, or parents of children who have been adversely affected by a vaccine.

Our genome report was released in 1988. National Research Council reports that have appeared in the past few months include a study on what to do with excess weapons plutonium generated by disarmament, how to compensate Vietnam veterans exposed to Agent Orange, and how to establish a biological survey for the United States. In all, we publish nearly 200 reports each year.

I see our basic function as serving as a bridge—a bridge that connects this country's scientists, engineers, and many others across this country, to Washington for matters of science policy. This is schematically illustrated in Figure 2. Groups of scientists serve as an intelligent filter to bring thoughtful analyses based on reality to government leaders. We hope to do this continuously throughout the course of education reform.

Well–what about standards?

Back in early summer of 1991, several major scientific and science education societies urged my predecessor, Frank Press, and the National Research Council, to undertake the enormous task of developing guidelines for K-12 science education standards.

These groups included the National Science Teachers Association, the National Association of Biology Teachers, the American Chemical Society, and the American Physical Society. Together, they perceived a need for a non-partisan, expert group to convene to develop science education standards. And the National Research Council has had an excellent reputation as an organization that brings together diverse groups to reach consensus.

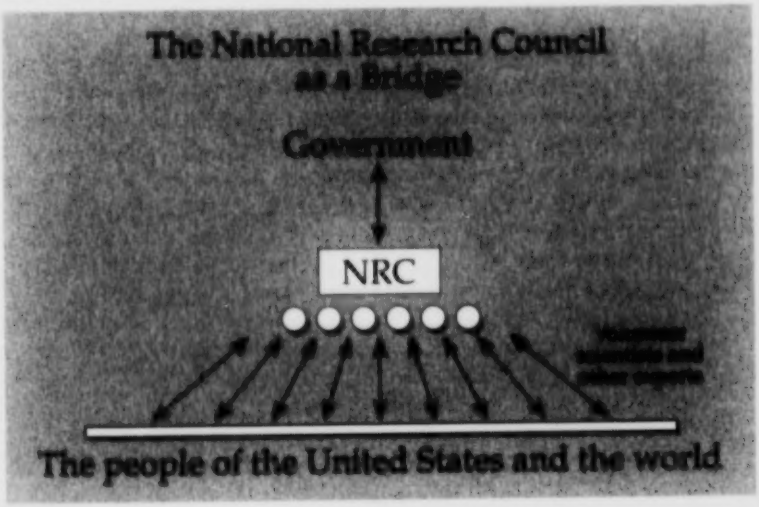
The National Research Council
as a Bridge
Government
NRC
scientists and
other experts
The people of the United States and the world

Figure 2

I am pleased to serve as the leader of the organization that has taken on this important project. I like challenges. And I see this difficult task as an appropriate challenge, both for us and the nation.

The National Science Education Standards are being developed for the following areas:

- **Content Standards** define what *all* students should understand and be able to do as a result of their school learning experiences. Ideally, this section of the standards will allow those who use the standards to discriminate between good and bad curricula, textbooks, et cetera. The content standards section contains a number of different subsections. It starts with a very important section called "Science as Inquiry." The point here is to emphasize a very different kind of science teaching than that which is traditionally taught in our schools. "Less is more" is a central theme that pervades the standards. It is my impression that the standards in other disciplines such as the arts and history will consist only of content standards. Our standards will contain much more.
- **Teaching Standards** provide a vision of what teachers need to understand and do to provide learning experiences for students that are aligned with content standards. For example, there is a new view of teachers as facilitators of cooperative learning, as "coaches" for students doing science, and they need to be taught how to teach this way. Likewise, teachers need to have control of their environment—time to meet with other teachers as profes-sionals, and so on.
- **Assessment Standards** identify essential characteristics of fair and accurate student assessments and program evaluations that are consistent with content standards, e.g., multiple choice word tests that cover all of biology are no good!
- **Program,** or **School Standards** describe how content, teaching, and assessment are coordinated in school practice, e.g., the whole is more than sum of its parts—it would not be good to teach only biology!
- Finally, **System Standards** describe how policies, programs, and actions outside of the immediate learning environment support high quality science programs, e.g., we need a materials supply center for science in each school district. We also need support for high quality teacher in-service programs.

What about the timetable? We are planning to release a full draft in early fall for extensive comments. The standards will be issued in final form in the winter of 1995. For the rest of my talk I'd like to address the question of why scientists should care about these science standards.

What I say may surprise you because I believe that scientists have a central role to play in precollege science education, starting in kindergarten. Accepting this responsibility will require that we as scientists make a concerted effort to connect with the rest of society in ways that have not been traditional for most of us. It therefore provides scientists with both a challenge and an opportunity. And—this is important—when the national science standards are released, they will serve as a useful tool to empower the involvement of scientists.

The national science standards will call for the kind of science that provides both an understanding of the basic concepts needed for success in our high technology society, and the acquisition of what I will call process skills. By process skills, I mean the ability to proceed step by step to solve a practical problem by examining the effect of changing one variable at a time. This is the type of education that one needs for success in the modern workplace, as well as for everyday living. And it needs to start in elementary school, where we can take advantage of the natural curiosity of children and their excitement for learning—before years of drill and rote learning cause so many of them to lose their interest in school.

We are very fortunate that outstanding hands-on science curricula for kindergartners through sixth graders have been developed and refined over the years in the United States. These age-appropriate units have been extensively tested by teachers and in the classroom. Each explores one subject in depth for eight weeks—such as plants, the life cycle of butterflies, or electric circuits. The equipment and materials are simple and affordable. The best units teach problem solving and process skill as well as scientific knowledge. And the teacher functions largely as a coach to students working in cooperative groups.

This type of science teaching exploits the excitement of learning through exploration that is natural to young children—and to scientists. By allowing reading, writing, and math to be taught as real experiences, this type of science can, and has, reinvigorated entire schools. And because children will demand more of the same kind of science experiences when they move into middle school, a dramatic change in science education that begins in the elementary years can be infectious—spreading throughout the entire school system as the students age. This is exactly what is happening in the Pasadena public schools.

Here is another crucial point. By giving each child a chance to contribute according to his or her particular skills, this type of teaching seems to make the biggest difference for those very children who are most at risk in our schools—those from home environments that are least supportive of standard book learning. This is vitally important for our vision of America as a democracy.

Now for the sad part. Even though this type of science teaching has been pioneered in several school districts in the United States, it has not spread. As a result, probably less than 1 percent of our elementary school students are being exposed to the type of hands-on science that they need for their future.

Here we come to the most fundamental flaw in our whole education system. Unlike the automobile or computer industries, *there is no continuous improvement cycle at work in our schools.* Instead, the bad things often drive out the good. This is exactly what happened to the outstanding high school biology textbooks that were developed in the 1960s, once the post-Sputnik reform effort that created them ran out of resources. The reason is simple—the system we have tends to select for the curricula that are the easiest to teach and to test. Hence an emphasis on science *words* instead of science concepts. And there is a real danger that, even with standards, we will do this again.

I think that I can identify several things that prevent a continuous improvement cycle in science education from working in most schools.

- A major improvement in the way we teach science will require each school district to maintain a consistent, organized effort over a period of ten years. This is about four times longer than the average term of a big city superintendent, so that the leadership and support for reform is often disrupted before it can make any major progress.
- Schools are constantly under pressure from political forces that require them to deal with emergencies and special interests. Because science education typically has no informed, consistent, local advocacy group pushing for it in most schools districts, it tends to get overlooked in a swirl of complex events.
- Most school systems operate in a hierarchical fashion that does not readily incorporate feedback from the schools. They therefore lack access to the real wisdom in the system—wisdom from the outstanding principals and teachers who understand what will and will not work and why. In my experience, the best science teachers often feel isolated and alienated by the school systems that employ them.

How are we going to change this tragic situation in our schools? The science standards will certainly help by giving us a direction. But standards alone will not be enough.

I have a specific proposal to make that calls upon a major resource that has not yet been exploited—the scientific, engineering, and medical communities. These communities have not traditionally been major contributors to the process of K-12 science education. Moreover, many scientists have acted with arrogance in proposing overly simplistic solutions for a complex problem. But we can be educated away from arrogance and made to appreciate the real heroism of the many outstanding science teachers in our schools. And when it comes right down to it, we *do* care deeply enough about the science education provided to young people to volunteer in huge numbers if provided with a meaningful and effective task.

Let me tell you a little about the Science Education and Health Partnership at the University of California at San Francisco (UCSF). This is a program that I helped start in 1987. Our program began when scientists met with a group of outstanding teachers, where we discussed the resources at our university and asked how we might be able to help. From this came a partnership with San Francisco teachers that initially focused on three things: organized donations of our surplus equipment and supplies, voluntary one-on-one partnerships between a San Francisco teacher and a UCSF scientist, and an annual science teaching contest judged by UCSF scientists in the schools.

I want to emphasize an important point. From its inception, our partnership has involved UCSF's most outstanding scientists. It was not a program designed by the Dean's office. Seven years later, this partnership has prospered in many unintended ways. We have sent more than 1,000 volunteers into the schools, and they keep returning because they find these contacts invigorating.

Even more important than the help we have given to teachers is the way that these many contacts have opened the eyes of those of us at the university. Through this program, we have become aware of a very important world around us that we had previously ignored. The benefits were unexpected, as listed below.

- **The Education of Scientists**
  Scientists learn to respect teachers, and they discover the true opportunities and problems in the schools.
- **Teacher Empowerment**
  Scientists become effective advocates for the goals of outstanding science teachers, who are often powerless on their own.

From my experiences in traveling around this country, I have come to realize that we urgently need an ingredient in each school district that is *completely new*. In Washington, D.C., for example, there are presently eighty different outside groups trying to improve the science and math curriculum, with little or no coordination among

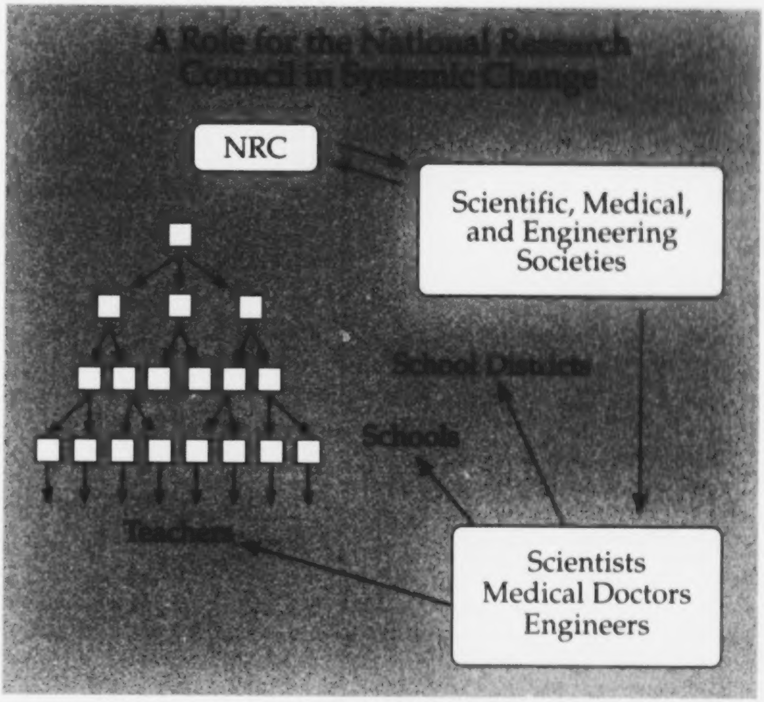
A Role for the National Research Council in Systemic Change
NRC
Scientific, Medical, and Engineering Societies
School Districts
Schools
Teachers
Scientists Medical Doctors Engineers

Figure 3

them. A much more effective approach would be for all of these groups to work together on a few major projects. But, unfortunately, the groups lack a decision making body that both the teachers and the others respect. In each school district, we need a central platform for continuous improvement in science education that is based on a local partnership of informed scientists and other citizens, together with a group of outstanding science teachers in that district and the district's science coordinator. The teachers' role here is key.

Time does not permit many details here, but I believe that there is also an important role for national scientific organizations to play in catalyzing the types of changes that I am suggesting for science education. By combining the resources of the many scientific societies, we can create an effective national network designed to inform and communicate with the type of local partnership group I have just suggested. In part, this network would rely on using existing scientific society newsletters to mobilize scientists and connect them to the resources they will need to promote major changes in their local school districts. There has also been a great

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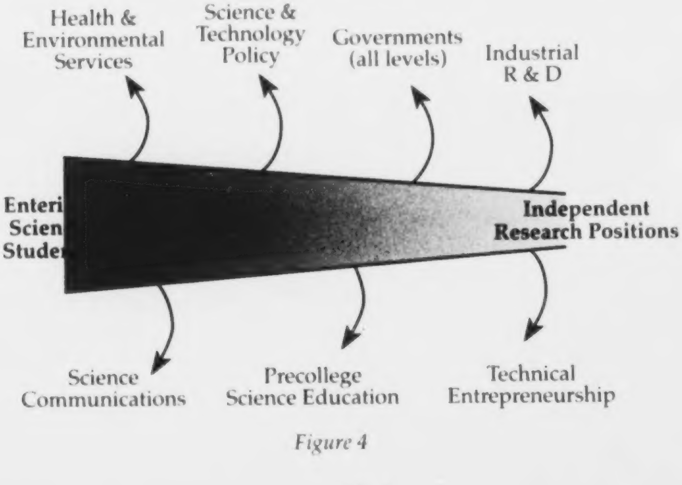
deal of talk about the need for a database on the Internet, which is specifically designed to aid scientists in their networking efforts. I would like the NRC to help coordinate these efforts.

What we are attempting to do in education is schematically outlined in Figure 3. The goal is to bring an increased rationality to society through the volunteer efforts of informed scientists. In each individual school district, the local conditions will be different and the situation will be much too complex for a "top-down" solution. Instead, I envision scientists as intelligent, local "adapters"—working in groups to adapt information provided through a much larger network to a local problem. They would be improving a school system—meanwhile providing feedback from their experiences that continually increases the wisdom available to everyone.

It is critical that all of the information flows in these diagrams be bi-directional, and that the scientists recruit other individuals with complementary expertise to join them as volunteers. Just as the NRC does in all of its work, these efforts would attempt to bring many different parties together as collaborators.

It would be a gross oversight to end this talk without discussing our universities. In particular, I see a special role for universities in science education reform. What we need from our universities in the 21st century are programs that first educate and excite large numbers of young people about science, and then are able to prepare them for a very broad range of highly valued careers—as illustrated in Figure 4. In particular, it is crucial for this country that one of these valued careers be precollege science teaching.



A Productive "Pipeline"

Health & Environmental Services
Science & Technology Policy
Governments (all levels)
Industrial R & D
Enteri
Scien
Stude
Independent Research Positions
Science Communications
Precollege Science Education
Technical Entrepreneurship

Figure 4

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I strongly believe that we will be providing for our country's future only when a large group of our most talented and energetic young people are choosing teaching careers. To me, this is a far better test of our educational system that any measurement we could design that is based on student test scores. It also has the advantage of giving us an instant, unambiguous reading of how well we are doing in our education investment.

In summary, I have four major points to leave with you concerning science education:

- Science should become a core subject like reading, writing, and math in grades K-12.
- At all levels, the material taught should be *interesting*, both to students and to teachers.
- The profession of science teaching must become an attractive one, which is possible to do well without superhuman effort.
- Last, but not least, the scientific community must accept responsibility for achieving the above three goals.

I would like to close by quoting the philosopher Alfred North Whitehead, who stated seventy years ago that:

> "The art of education is never easy. To surmount its difficulties, especially those of elementary education, is a task worthy of the highest genius . . . (But) When one considers . . . the importance of this question of the education of a nation's young, the broken lives, the defeated hopes, the national failures, which result from the frivolous inertia with which it is treated, it is difficult to restrain within oneself a savage rage. In the conditions of modern life the rule is absolute, (a country) that does not value trained intelligence is doomed."

Teachers: The Vision Supported

Jan Tuomi

What does "standards-based systemic reform" mean to a teacher? An immediate reaction might be "Oh, my aching back!"—to elementary teachers already burdened with addressing the problems of society represented in their classrooms, such as drug and alcohol abuse, domestic violence, cultural diversity, ethics and values, or hunger and homelessness. The typical teacher cares very much about each of these issues and tries to address them in addition to the challenge of teaching children to read, communicate effectively, solve numerical problems, appreciate the contributions of a variety of cultures to their community, understand natural phenomena, and learn to think—in addition to the possible "bonuses" of artistic and aesthetic development, music appreciation, and physical fitness.

A support system is indeed necessary to implement the vision of standards-based science education. Before going to Washington, I was a teacher for twenty years, so I am honored to be able to represent teachers in suggesting to you what that support needs to be. And I am optimistic that you can make a significant contribution toward making the vision a reality *in classrooms* where reform *must* happen to benefit children.

In my interaction with groups of parents, teachers, and scientists, there is an amazingly focused agreement of what the desired outcomes are for science education. Many state that the most important outcome is an "average" person who is curious, who appreciates the natural world, who can think and make decisions using factual evidence and careful analysis, and who knows enough about the content of various scientific disciplines to apply their understanding to solving a variety of problems. Many of your professional groups will add that more, and more diverse, individuals should be recruited for and retained in the scientific and technical fields; and that the "average person" should place a higher value (and funding level) on science and scientific research. In my opinion, there is very little disagreement between scientists and teachers.

But we have not yet addressed the central question: 'What constitutes the essential support teachers need?" The research compiled by the National Science Resources Center—a K-12 science education program supported in part by the National Academy of Sciences for the past 8 years—points to several teaching and learning goals and recommends several reform strategies. The science education materials and teacher training institutes in which so many teachers took part in the 1960s failed to produce widespread beneficial results. The National Science Resources Center has studied isolated areas where the innovations of the 1960s persevered and succeeded. The experimental evidence from this search finds that the successful enterprises have these elements in common:

1. The availability of high-quality, inquiry-centered science curriculum units that are appropriate for children;
2. Teacher education programs to prepare and support elementary teachers to teach hands-on, inquiry-centered science;
3. Support systems for supplying science materials and equipment to teachers;
4. Assessment methods for evaluating student performance that are consistent with the goals of an effective science program; and
5. Administrative and community support for an effective science program.

The National Science Resources Center has used this information as the theoretical basis of a leadership development initiative with 106 school districts across the nation. Evidence from this experiment suggests that these elements are indeed critical.

Furthermore, to elaborate on the administrative and community support necessary—teacher support must be *comprehensive and systemic, collaborative, and sustained for at least a decade.* The planning and implementation of local reform must include administrators, teachers, school boards, parents, and representatives of community business, industry, and higher education. Overall, the planning must take into account the goals and views of all these groups—a multifaceted learning and marketing challenge. Partners must understand that change is a process—not an event.

The experimental evidence also suggests that a good place to begin a reform effort is at the elementary school level. Improvement at the elementary level yields the largest dividends. Research on students' attitudes shows that as many as 50 percent of the students at age twelve find science boring or too hard, and plan to take as little science as possible in the future. Simply opening up this "crimp in the pipeline" can yield very large potential dividends in more students choosing to take science. It certainly is a first step in enabling historically underrepresented groups to have access to scientific literacy or science careers. Also, the science curriculum at the elementary level is not as entrenched in tradition as high school, so it's easier to change.

As the participants in this forum go forth to address standards-based, systemic reform of science education, I recommend that *all five* of the above elements be addressed in planning comprehensive, long-term support efforts. All participants in local and national initiatives need an ongoing education in recent research and successful practice that addresses each of the five elements. And, with reference to number five, there is a special role for scientists in their local school districts in becoming advocates for an effective science program and steady support for that program.

[VIDEO TAPE OF CLASSROOM STRATEGIES FOR SCIENCE EDUCATION]

If I might take the liberty to speak for my fellow teachers, I would like to assure the scientific and technical research community that we welcome a partnership—one in which we shall learn from each other.

When I worked with the scientists involved in the partnership programs at the University of California at San Francisco, I found the partnership tricky to get off the ground but very rewarding on both sides. As a teacher I gained an appreciation for what "real" science is and how it is done. My fellow teachers and I were amazed to find out that scientists were regular people! We were very gratified that our scientist colleagues came to appreciate how hard we work, and that they became more familiar with the conditions under which we routinely work. My personal opinion is that the biggest payoff for the partnerships might be this one—although initially unintended—that more members of a community would recognize the professionalism of teachers and truly appreciate their contribution to the community.

On the other side of the partnership, I believe the scientists enjoyed very much learning more about how children learn. Many have commented to me what a refreshing change of pace it is to grapple with broad concepts, in contrast to their highly specialized research. All have been very satisfied that they were doing something concrete to contribute to the solution of a problem, and were especially glad to have ongoing help from the partnership program in finding the right niche in order to make the most significant impact possible in the time they had to spare.

In closing, I would like to reiterate that teachers would appreciate becoming professional equals, sufficiently supported to become professional science teachers. You will find no other group of stakeholders more dedicated to the ideal of success for every child.

K-12 Science Education: A Teacher's View

Penny Moore

Science education has experienced significant changes over the past two decades. Indeed, science and its applications have changed enormously. Science is now vital to good citizenship, performance in the workplace, and everyday life. Overcoming the economic and social problems now challenging the United States is dependent upon the success of the educational system.

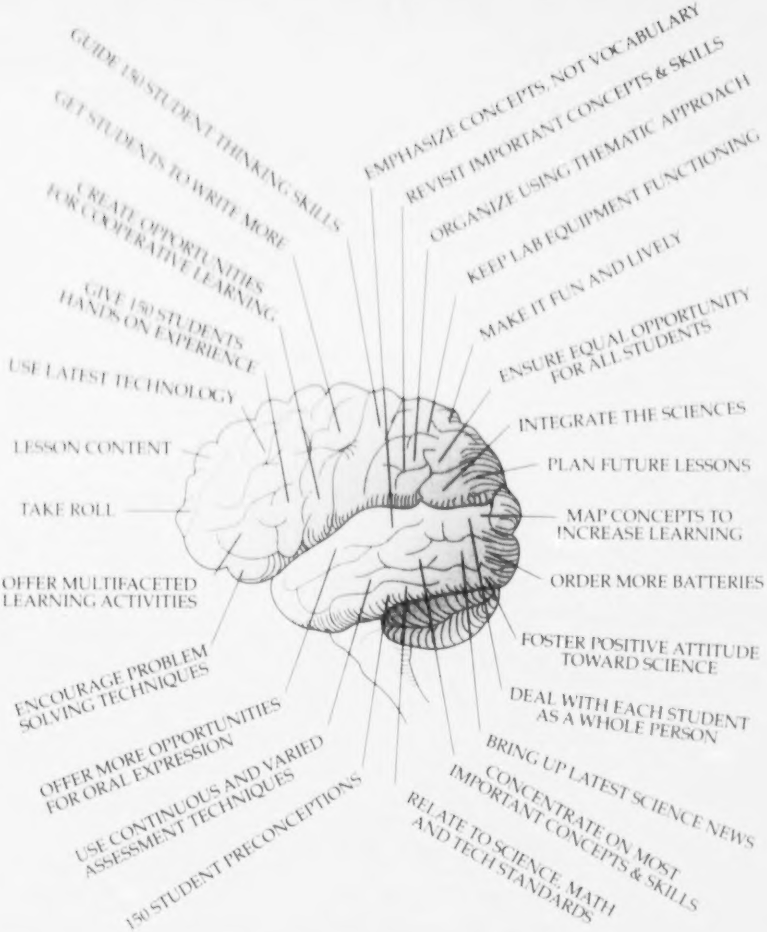
We are beginning to understand how students learn science. New tools are becoming available to connect classrooms to the information superhighway and to capture and tantalize the imagination of even the most distracted or disinterested young people. It is time to re-tool and re-design the entire K-12 science education system, employing the same principles and methods used in the practice of science itself.

Present Day Science Teachers and Classrooms

What is a modern science teacher's view of good science instruction? Although not all teachers have reached the same understanding, the changes mentioned here can be found in more than 10 percent of California's schools and are present in at least 10 percent of the states.

One of the greatest concerns of teachers is the students' lack of motivation to learn science. Walk into any classroom today. What do you see? Are many of the kids bleary-eyed from all night TV, passively waiting for canned fun? Is this what's happening in your neighborhood classroom? Of course not! But why not? Many teachers have learned to fight fire with fire. They put a little fun and magic in their classes (McCormac 1990). They also begin each lesson with a problem or story that is of great interest to the students, or a topic students recognize as being important to society. They teach students practical skills such as rewiring lamps or fixing a toilet. They talk about why you wear a seat belt or how to recognize a heart attack. Then these teachers bring in scientific concepts.

But teachers have to know these "good" stories of science, or they must know how to direct students to find them. This is one area practicing scientists are of enormous help, but much more is


GUIDE 150 STUDENT THINKING SKILLS
GET STUDENTS TO WRITE MORE
CREATE OPPORTUNITIES FOR COOPERATIVE LEARNING
GIVE 150 STUDENTS HANDS ON EXPERIENCE
USE LATEST TECHNOLOGY
LESSON CONTENT
TAKE ROLL
OFFER MULTIFACETED LEARNING ACTIVITIES
ENCOURAGE PROBLEM SOLVING TECHNIQUES
OFFER MORE OPPORTUNITIES FOR ORAL EXPRESSION
USE CONTINUOUS AND VARIED ASSESSMENT TECHNIQUES
150 STUDENT PRECONCEPTIONS
EMPHASIZE CONCEPTS, NOT VOCABULARY
REVISIT IMPORTANT CONCEPTS & SKILLS
ORGANIZE USING THEMATIC APPROACH
KEEP LAB EQUIPMENT FUNCTIONING
MAKE IT FUN AND LIVELY
ENSURE EQUAL OPPORTUNITY FOR ALL STUDENTS
INTEGRATE THE SCIENCES
PLAN FUTURE LESSONS
MAP CONCEPTS TO INCREASE LEARNING
ORDER MORE BATTERIES
FOSTER POSITIVE ATTITUDE TOWARD SCIENCE
DEAL WITH EACH STUDENT AS A WHOLE PERSON
BRING UP LATEST SCIENCE NEWS
CONCENTRATE ON MOST IMPORTANT CONCEPTS & SKILLS
RELATE TO SCIENCE, MATH AND TECH STANDARDS

A Science Teacher's Brain

Figure 1

needed. Science stories can involve many different groups and cultures. Science can be made exciting and productive by, for example, naming lab tables after scientists from underrepresented groups, by sharing stories of contributions from a variety of ethnicities, and bringing each student to a higher level of literacy through varied activities and assessment items. Teachers are becoming aware of these stories and role models, but we need more.

As you can see from the picture of a teacher's brain *(Figure 1)*, motivation and equity are but two of an overwhelming array of problems and tasks teachers have to attend to in their teaching day. Teachers may concentrate on the student, but they still need a good scientific background and educational materials for useful scientific learning to take place. The number one factor cited by both elementary and secondary school teachers as a serious problem is the need for more materials (NAEP 1992).

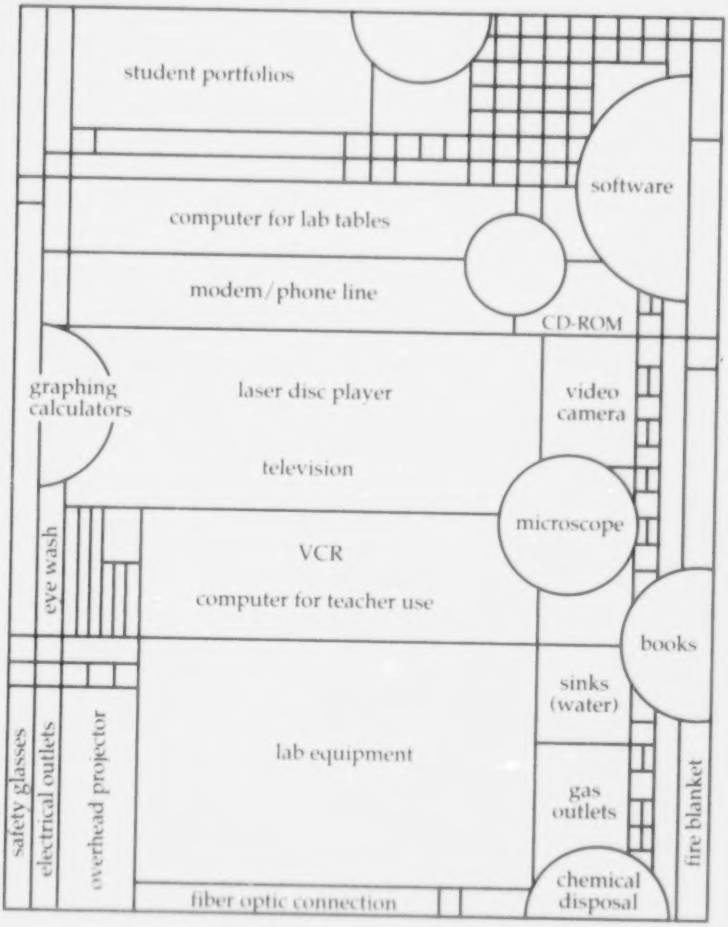
Another factor influencing`teaching are major research-based reforms in curriculum, including Project 2061, Scope, Sequence, & Coordination, several state frameworks, and the National Academy of Sciences National Science Standards project. Common characteristics in curriculum reform include:

- Organizing science content by themes and sequencing instruction to correspond with student development patterns;
- Coordination or integration of activities from biology, chemistry, earth/space science, and physics;
- Pacing instruction to build on previous concepts and experiences, and revisiting concepts at a greater depth and breadth;
- Emphasizing student-centered, hands-on activities to engage all students in the learning process, and;
- Focusing on concepts and skills rather than vocabulary.

One exciting example of the new curricular reform is the PRIME Science program (Johnson 1994). With help from the National Science Foundation, six sites across the United States are adapting and enriching the Salters' Science Program (Hayward 1994) from the University of York, United Kingdom. This is a fully integrated, coordinated science program for grades six to ten, revisiting and expanding upon major concepts and skills each year. Every lesson builds on knowledge or interests that students bring with them from their everyday experiences. The majority of the materials are written for the new teacher or teachers outside their major discipline area. Teachers using the trial materials report it is the most interesting program they have taught.

Another change, using recent cognitive research on student learning (Mestre 1991, Minstrell 1989), is that teachers are employing a richer variety of assessment techniques. Continuous assessment encourages students and teachers to identify and confront misconceptions (McDermott 1991), improves learning, and offers opportunities for success to a wider range of student learning methods. Open-ended questions and lab practicals are now joining multiple choice examples. Longer term, more in-depth progress is monitored in portfolios.

The variety of student activities and teaching techniques is also rapidly increasing. Cooperative learning is popular with most students and teachers. Along with more opportunities for writing and oral presentation, students participate in role playing and model decision making tasks, collecting and displaying data electronically, learning about science and technology challenges, and conducting research on science related careers. The sage on the stage is now a guide on the side.


student portfolios
software
computer for lab tables
modem/phone line
CD-ROM
graphing calculators
laser disc player
video camera
television
microscope
eye wash
VCR
computer for teacher use
books
sinks (water)
safety glasses
electrical outlets
overhead projector
lab equipment
gas outlets
fire blanket
chemical disposal
fiber optic connection

Science Classroom Equipment

Figure 2

From the outside, the modern science classroom may look the same. That's because much that is new is hidden or locked behind cabinet or storeroom doors *(Figure 2)*.

Teachers need to know how to use an ever-changing array of equipment. They need time to learn how to operate and repair the equipment. They also need time to write proposals for new equipment and to learn how to integrate these resources into their lessons. CD-ROM and laser discs add to the complexity of available tools, and keeping up with the ever-growing electronic data bases available to students can be overwhelming.

It is a common frustration for teachers that even when a school can get major equipment through special appropriations or grants, the school does not have enough money to purchase discs, software, batteries, stopwatches, or put in a dedicated phone for the modem.

Effective Pre-Service Teacher Training

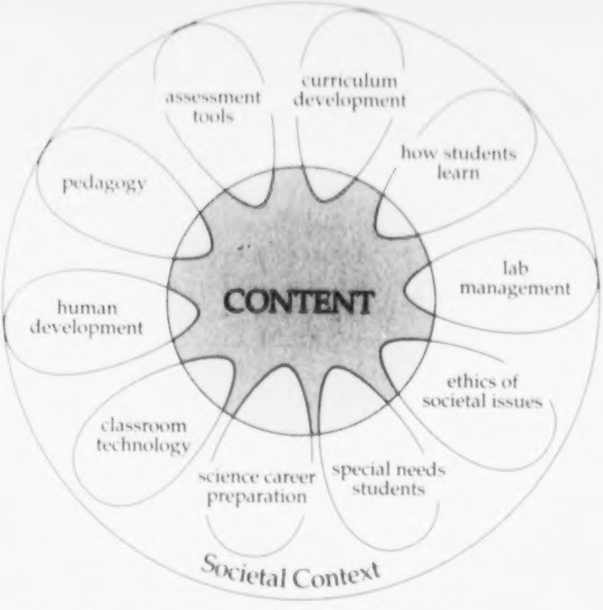
The growth and changes in scientific disciplines, the need for scientific literacy for all citizens, and the use of interdisciplinary approaches to K-12 science teaching calls for new models of training science teachers (Glass, Aiuto and Anderson 1992).

I recently surveyed 300 secondary level science teachers. Ninety-one percent were concerned about the lack of science courses in teacher preparation. What the teachers valued most was a mentored classroom experience, the longer the better.

With this in mind, as the figure suggests by centering on science content *(Figure 3)*, college and university science faculty must get involved with science teacher education, both as leaders of content courses and as partners in the mentoring process. Together with scientists and engineers from industry, medical, and government facilities, teachers with enough background can set their instruction in a current and useful context. One step in this direction is the TEA(CH)$_2$EM Program (Sauer and Wemmer, Rohwer 1993).

It is also time that teachers take responsibility for the future of their profession. Experienced teachers should not only be largely responsible for the curriculum for science teacher training, they should organize and seek training themselves to effectively mentor new teachers in their schools for a five year period. The national average age of a science teacher is forty with thirteen years of teaching experience (Weiss, Nelson, Boyd and Hudson, 1989). There should be ample mentors to be found.

Science teacher training should still involve traditional science education researchers for seminars on such topics as how students learn science, the nuts and bolts and tricks of classroom manage-


assessment tools
curriculum development
how students learn
pedagogy
lab management
CONTENT
human development
ethics of societal issues
classroom technology
science career preparation
special needs students
Societal Context

Pre-Service Teacher Education Schematic

Figure 3

ment, handling special student needs, questioning techniques, and meaningful assessment of concepts and skills. These education faculty would act as partners with the mentor teachers and scientists in providing complete, practical training.

Changes of this magnitude require a period of years and a carefully organized transition accompanied by credentialing and peer assessment mandates.

Effective In-Service Teacher Training

Science, science education, and technology are changing so fast it is essential that teachers already in the classroom be given a yearly opportunity to get updated. The overwhelming task of good science teaching leaves teachers with little time to reflect on their teaching, update their knowledge, network with other teachers, or pursue research on their own ideas in a significant manner. Science teachers need an "eleventh month" for these professional development activities. This "eleventh month" works well if it is organized *by* science teachers *for* science teachers, with scientists and science educators as partners. Teachers should receive full pay for this additional month, with travel and living expenses if the month is spent away from home. Present in-service institutes are excellent precursors to this plan, and the best features of these programs should be utilized.

One example of a teacher designed program is the Science for Science Teacher's Program (Moore and Richards 1993), starting in 1985 with funding from the National Science Foundation and later from the Noyes Foundation. This popular program brought fifty junior high/middle school level teachers each year from around the country to Berkeley for a month of multidisciplinary, thematically organized science instruction by Berkeley science faculty. Computer training, tutorials, field trips, and extensive laboratory and group work provided a comprehensive curriculum for enhancing teacher scientific literacy. Several programs now exist at other sites with a similar format. Other successful examples of partnerships are discussed in this proceedings or may be found, for example, in Sussman's book, *Science Education Partnerships*.

The format was successful with teachers because they felt comfortable being in a program clearly controlled by and instructed by classroom teachers (rather than by research scientists or former teachers). NSF and other funding agencies have yet to put a classroom teacher in charge of teacher enhancement.

Nevertheless, it would create an enormous financial and professional advantage to have the "eleventh month" become a regular part of science teaching. Science teaching must become competitive with other jobs if it is to attract top candidates, especially from underrepresented groups. One suggestion is that funding be awarded to teacher-led partnerships, and after a period of transition years, be funded by local systems as a part of a science teacher's contract.

What is Needed to Improve K-12 Science Education?

Based on research and on experience in other countries, most teachers trying out the new models, methods, and technologies express excitement, enthusiasm, and commitment. What is missing from the picture of the science classroom?

I am the physics teacher in a small public high school, and I need help. I have total responsibility for the 50 percent of the student body who opt for honors physics. I have no external assessment of the content I teach, few people to discuss content with, and find our state framework (California) of little help in determining and updating my curriculum. Textbooks are more a source of irritation than a tool. My major feedback is from talking to former students who have taken physics in college. How easy it would be not to keep reading *Science News, Science,* teacher journals, not go to meetings, and just keep teaching the same thing in the same way year after year. No one would notice.

I can still remember the day when I realized how tragic the situation was. I wrote all the National Academy members I'd heard of in California hoping they would do something. I wrote the California State Department of Education and asked why they didn't have any Berkeley science professors working on the state framework. I started collecting textbooks and national curricula from other countries for guidance. I read the precursors for *Science for All Americans* of the AAAS (Project 2061, 1989). I was delighted when the National Science Teachers Association initiated the Scope, Sequence, & Coordination Project (SS&C 1992), and finally the Academy took some action. At the moment I use the British standards in the shortened form (National Curriculum Council 1991, or the summary in *Promises to Keep: Creating High Standards for American Students,* 1993).

In my view, what we need most from practicing scientists is standards for scientific content and skills, in a form that is easy to use and can be updated yearly. I would like to see a set of goals for scientific literacy (hopefully achieved by the tenth grade), and a scientific content standard for college admission. Having these goals will make assessment and change much more effective. I am hoping the National Academy will handle this task.

Furthermore, we need careful, impartial compilation of assessment data on the scientific literacy and attitudes of students over a period of several years. We need to know which programs work so we can make informed choices for our classrooms. The national assessments (NAEP 1992) do not provide enough information on individual students in a given program over a period of years. It is time we take money Congress allocates to the Department of Education and re-directs to special interests and put it to work for all of us.

We also need a review of our teaching by our peers and experts. Equally important, science teachers need regular "eleventh month" enhancement and updating; time to adapt their courses to new standards; a chance to look over new teaching strategies and technologies; and the opportunity to form networks with other teachers, scientists, and educators.

Overall we need a coordinated, long term plan that makes use of the unique qualities of each group or entity involved. Suggestions for participation by each party are given in Table 1. Much of the initiative for reform goals 3 and 4 (*Promises to Keep,* 1993) has come from the White House. Yet few of the obstacles to these goals have

Suggestions for Action

Entity	Purpose	Action
K-12 Science Teachers	Strengthen and improve the teaching profession	• Develop professional standards for new and experienced teachers • Design and run "11th month" enhancement/updating courses
Practicing scientists University Industrial Government	Ensure excellence of scientific content and skills in K-12	• Develop and update standards • Seek mentorships/partnerships with teachers • Advise on text adoption, stories for societal context, teacher evaluation
Federal government	Evaluate education programs, then support and disseminate the best Fund "11th month" programs Reward scientists for participating in the reform	• Collect and collate data on students and programs over extended period • With teachers and states, organize, fund, and evaluate month-long summer professional development for all K-12 science teachers • Add condition for scientific research funding that the results of the research should be transformed with the help of teachers into classroom materials
State government	Improve communication, coordination and dissemination Ensure professional competence of teachers and classroom materials	• Develop networks among teachers, between teachers and scientists and educators • Design with teachers and pre-service institutions a gradually improving credentialing and assessment program • Use international standards to determine the usefulness of classroom materials
Colleges and universities	Mandate that all graduates be scientifically literate Develop collaborations between practicing scientists and educators for pre-service and in-service teacher training and research on learning	• Gradually increase science admission requirements to 4 years h.s. science • Define literacy requirements and/or courses needed • Integrate K-12 and two year colleges • Provide sites for "11th month" activities • Encourage/reward collaborations
Testing services	Evaluate scientific literacy	• Include science questions on SAT, GRE
Industry	Ensure excellence of scientific skills and content	• Develop education programs which help science classrooms share or purchase useful equipment • Advise teachers on classroom safety • Provide sites for "11th month" activities
Parents/ Community	Increase scientific literacy	• Foster and participate in activities and events which share the excitement and importance of science

Table 1

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been identified and no well coordinated strategies proposed and implemented. The matter of science education, along with its cousins mathematics, technology, and engineering education, is so vital to our nation's health that it only seems appropriate that the coordination for the effort come from the same high level. Any program must heavily involve those people most responsible for the mission's success, namely classroom teachers.

K-12 science education has at its core a cadre of excellent teachers and many talented people anxious to help teachers succeed, but working independently and without coherence. A logical beginning would be to start with this group, define goals through standards, use the best teaching methods known to achieve these goals, gather enough meaningful data over a long enough period of time to be able to assess the goals, and then build a stronger, continuously updated education program on the assessment results.

Conclusion

It is time we recognize science in the schools for what it is: a core subject, along with English and math, essential to our economic, physical, and societal well-being.

We can no longer ignore the special needs of science instruction. All students need a course that develops their scientific literacy and critical thinking skills every year. Each science program needs meaningful, useful content and skill standards to drive and continuously update the curriculum content and enable useful assessment. We have the technology to collect enough data so that we can learn which new programs, tools, or techniques work (in which situations), and the ability to disseminate this information. Science teachers must articulate their needs and develop opportunities for professional development and the strengthening of their profession. We need a national plan that gets the many different participants working coherently towards a common goal.

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Reform and National Standards:

Implications for the Undergraduate Education and Professional Development of Science and Mathematics Teachers

William E. Kirwan

Clearly, scientists and teachers have much to offer to the national dialogue on standards and reform in science and mathematics education. What impresses me so much about the nature of the Sigma Xi forum is its focus on local initiative. As Chester E. Finn wrote in an a recent article in *Change* magazine: "We can restructure schools until we're blue in the face, buy new textbooks until we're broke, overhaul curricula until *we're* exhausted, and retrain teachers until *they're* exhausted. At the end of the day, however, our educational outcomes will improve only when something" (or, I add, someone) "causes youngsters to learn more than they have been."

In a nation with a highly decentralized K-12 school system and a multitude of independent teacher preparation programs, progress—to paraphrase a current television commercial—will have to be measured one school district at a time. This fact does not diminish the need for national educational standards, major curriculum projects, and other comprehensive reform efforts. Rather, it recognizes that unless educators at the local level embrace reform concepts, mold them into ideas they can own, have opportunities to share their experiences and learn from others, meaningful reform will not move from the pages of well-intended reports to the nation's classrooms.

In my comments, I will talk about the impact of the science reform efforts to date, attempt to identify some of the common elements in two reform efforts currently receiving a lot of attention, and offer some comments on what new standards and reform might mean for the way we at universities prepare teachers in the future and offer in-service support for those already in the classroom.

The Impact of the Reform Movement

Many tend to think that the reform movement is relatively new but, of course, it isn't. As a reaction to the Soviet Union's success with Sputnik in the late 1950's and early 1960's, at least two major educational reforms were launched in this country, one aimed at changing the mathematics curriculum—the so-called New Math—and the other focused on college and pre-college physics. I think most of us would agree that neither of these movements resulted in lasting change. This is a rather sobering fact for those of us involved in reform today. Clearly, we must understand why past efforts failed if present initiatives are to succeed.

I know more about the New Math movement and offer the view that at least part of the reason for its failure was the lack of involvement of people at the local level in the reform process. Parents and teachers never did understand the rationale for the reform and, consequently, never really supported its implementation. In the case of the physics reform effort, I understand that although it had little impact on actual classroom activities, it at least continues to serve as a basis for some of the current thinking about the kind of curriculum students of physics should be offered.

The more recent reform efforts result largely from the outcry following the publication of *A Nation at Risk* in 1983. Since 1983, hundreds of reports have been written on educational reform, and enormous human capital has been expended developing new curricula and writing new texts. What is the impact of all this effort? Sadly, I believe most of us would agree that the answer is, "Very little."

A recent report released by the National Science Board supports this view. It cites a longitudinal study done by J.D. Miller and L.K. Pifer of the Social Science Research Institute. In this study, a national sample of 1993 high school seniors was asked a series of questions about basic scientific concepts. The students' responses were compared to responses given to the same questions by seniors in 1990. The results are discouraging.

For example, only 39 percent of seniors in 1990, and 36 percent in 1993, believed that humans developed from earlier species. Fewer than half the students surveyed thought there were probably other planets where life could have developed, and fewer thought this in 1993 than in 1990. Only slightly more than 40 percent of the students in both surveys thought science did more good than harm, and fewer thought this in 1993 than in 1990. And almost 40 percent of students in both surveys believed there are "lucky" numbers.

Not only did the responses to these and other questions indicate a lack of scientific literacy among a large number of high school graduates; they also showed that the number and percentage of students who demonstrated such literacy declined from 1990 to 1993.

And if this high school survey were not troubling enough, the attitudes of students in the lower grades toward mathematics and science suggest that educational reform has not yet taken hold in the primary schools either.

In a study done by the Educational Testing Service, thirteen year olds were asked their opinions on the importance of mathematics.

In 1978, 50 percent of the students said they would like to take more mathematics, whereas, in 1990 only 43 percent expressed an interest in additional courses. To the statement, "what I learn in science is useful," 58 percent of thirteen year olds agreed in 1978 but only 52 percent agreed in 1990.

But the news is not all bad. The most recent National Assessment of Educational Progress (NAEP) tests show that, after more than a decade of no change in scores, the most recent data, obtained for 1990, indicate a slight increase in performance for nine and for thirteen year olds in both science and mathematics. Nevertheless, there seems little doubt that the reform movement has yet to have the desired impact on student performance. Given the magnitude of the effort, is it reasonable to ask why more progress has not occurred? There are undoubtedly many reasons, but three seem especially important to me.

First, there appears to be a tendency for people to see the need for reform as a national and not a local issue. Put another way, when asked if our nation needs to improve science and mathematics education, most people will say yes. But when asked if their local schools need such reform, many think not. A recent Harris survey asked parents how they rated their children's schools, their community's schools, and the general quality of the nation's schools. Grades of "A" or "B" were given to their local school by 70 percent of the survey participants, while 50 percent gave those grades to their community's schools and only 20 percent gave an "A" or "B" to the nation's schools.

A similar survey of superintendents found that 71 percent gave high marks to schools in general and 90 percent gave high marks to their schools. Another Harris survey of high school graduates found that 68 percent thought they had learned math well, 66 percent thought they had learned to write well, and 78 percent thought they had learned to read well. Yet when university officials were asked to rate the same graduates on the same three dimensions, the favorable ratings where 27, 18, and 33 percent, respectively.

It's interesting to note that when students in Japan and China were asked questions about how much they had learned in school, they gave themselves much lower marks than did their American counterparts.

As Chester Finn wrote when commenting on these results, "If the children think they're doing pretty well, if parents believe their children are doing well, if the public thinks its local schools are doing well, and the teachers and administrators in those schools agree with this appraisal, why should anyone feel inclined to alter his or her actual behavior, demand different results from themselves or their children *or* agitate for significant changes in the schools?" This is a classic example of the "Lake Wobegon" effect. Locally, everyone is above average; it's the rest of the country that is failing.

A second reason the reform movement has not yet had the anticipated effect is that initial efforts have been too focused on finding a "silver bullet," a universal solution developed by committees operating at the national level. Sheila Tobias makes this point well in her book, *Revitalizing Undergraduate Science: Why Some Things Work and Most Don't*. Tobias says, "... looking closely at various proposals for change, one finds they oversimplify extremely complex processes and favor theoretical, universal solutions over more modest, incremental change .... The search for a single universal solution to the problems of teaching and learning science [at college] will inevitably be disappointing. The reason change is pursued at the level of instructional materials and teaching materials and teaching techniques, I believe, is not because anyone really expects a perfect course or a universally applicable set of pedagogies to be devised, but rather because of a habit of doing reform in this manner. The temptation is to solve a problem with a product because, for innovators and funders alike, the messy, intensely local alternatives are harder to conceptualize."

A third reason for the inadequate response to the reform movement is that too little thought and effort have gone into ensuring that teachers have the support, knowledge, and skills necessary to make the reforms work. A common element of most reform proposals is that students should learn science from a more conceptual and practical point of view. This means that their teachers must have a broad understanding of science and the inter-relations among its various disciplines, and that they must be equipped with new, relevant examples.

The median age of the nation's K-12 science and math teachers is in the mid-forties, which means that most teachers have been out of school for more than twenty years. Moreover, at the secondary level between 30 percent and 40 percent of teachers of math and science had some other subject as their college major.

At the elementary level the situation is even worse. For example, only 43 percent of the eighth grade mathematics teachers in the nation majored in mathematics or math education. For reform to be successful, we must involve the K-12 teachers in the effort, and we must make it possible for them to acquire the skills necessary to implement the reforms successfully in their classrooms.

Joe B. Wyatt, Chancellor of Vanderbilt University, made this point in an article he recently wrote for the *Washington Post*. Chancellor Wyatt said, "If the implementation of medical research were as ineffective as that of education research, our children might still suffer from polio." Wyatt goes on to say that, "A fair litmus test for research performed in professional schools is that it must be meaningful to the profession's practitioners, not just to other researchers. Education research fails that test."

In summary then, it is my view that if we are to successfully implement meaningful reform in science and mathematics education in the schools, we must get people at the local level to understand that the present failings occur in *their* schools, not just schools elsewhere; we must involve the practitioners in the development of the reform agenda; and we must offer teacher preparation programs and in-service training that will enable our K-12 teachers to successfully carry out the reforms. Put in these terms, it all sounds deceptively simple. Of course it is not. Enormous effort must be made and revolutionary change must occur if any one of those three objectives is to be accomplished.

Reform Initiatives

One reason I feel some optimism about the ultimate success of the reform agenda in science and mathematics education is the extent to which the research establishment has embraced the movement. The National Science Foundation (NSF) has shown real leadership by promoting and supporting programs aimed at improving the educational experience for undergraduates. And, the National Research Council (NRC) has made improvement in undergraduate science education one of its top priorities. I understand that grants to NRC support more than one hundred people actively working on reform initiatives. As part of its effort, NRC has launched a substantial project aimed at developing a set of standards for science education.

A further indication of NRC's commitment is the fact that a year ago it created a new standing committee named the Committee for Undergraduate Science Education. The charge to this committee is to develop strategies that will improve science literacy for all undergraduates. I am privileged to serve as a member of this committee, which consists of other college presidents, deans, science faculty, faculty from two year colleges, and people from the private sector.

With this kind of commitment from NSF and NRC, I believe we have a reasonable chance of gaining support for educational reform from the nation's major research universities. And if this occurs, I feel confident that the reform efforts will take hold nationally.

Among the various mathematics and science education reform initiatives already underway, two seem to me especially worthy of support. In saying that, I am not implying others are less worthy. Rather, I am only acknowledging that I know something about these two and that they satisfy the criteria for success that I have mentioned.

The first is the work of the National Council of the Teachers of Mathematics (NCTM), an organization of nearly 100,000 teachers of mathematics, mathematics educators, and professional mathematicians. In 1986, NCTM launched an effort to develop curriculum and evaluation standards for school mathematics in grades K-12. The initial work on the standards was carried out by four working groups each consisting of a cross-section of classroom teachers, supervisors, educational researchers, mathematics educators and professional mathematicians.

Drafts of the standards were sent to all members of NCTM, other professional organizations, and local school districts. More than 1,000 comments were received. Revisions in the draft were made based on these suggestions. The final document was approved by NCTM and endorsed by the Mathematical Sciences Educational Board of the National Research Council, as well as by many other professional organizations concerned with mathematics education.

I will not attempt to describe these standards in any detail. Many of you may be better acquainted with them than I am. Suffice it to say that the standards place a premium on the students' ability to work collaboratively and to use mathematics to solve problems that arise in their everyday experiences.

An important element of the NCTM standards is the degree to which they focus not just on the content of the curriculum but also on the work of teachers and the teaching enterprise. The standards place the teacher in the role of a facilitator of the learning experience rather than as the primary source of knowledge. Thus the standards call not only for different material in the classroom, they also call for a different kind of classroom experience. Obviously, this means we need mathematics teachers equipped with new kinds of skills and learning strategies, if we are to implement the NCTM standards effectively.

The second reform project that I want to comment on briefly is Project 2061 of the American Association for the Advancement of Science (AAAS). As its name suggests, this is a long term project. For those who might not be aware, the year 2061 was chosen not just because it's well into the next century. It's also the year Halley's Comet will return. This project began in 1985, the year Halley's

Comet came near the earth and the seventy-six year interval between these dates carries the symbolic message that education is for a lifetime.

Like the NCTM project, Project 2061 has been developed by teams of science teachers, school administrators, science educators, and professional scientists. Plans for implementation are being developed with the understanding that local jurisdictions must be thoroughly involved.

An underlying principle of the project is that science education is for *everyone*. More than most other reform initiatives, Project 2061 focuses on the need to encourage more women and minorities to pursue careers in science, engineering, mathematics, and other technical fields. It also incorporates social sciences into the reform effort.

As with the NCTM standards, Project 2061 is concerned not only with what students should be taught but also with how they learn. Specifically, changes in the traditional teaching structure are advocated in order to soften the boundaries between scientific disciplines; place greater emphasis on connections among the disciplines; reduce attention to the learning of facts; increase knowledge of general overarching concepts; and promote learning through raising questions and exploring hypotheses in group settings.

It seems clear that these two initiatives, the NCTM standards and Project 2061, will be at the forefront of the reform effort for the foreseeable future. Both have gained wide acceptance among science educators, teachers, and professionals in the disciplines.

It is interesting to see that they contain many elements in common, not simply in terms of the methodology used to develop the reforms and the careful attention paid to involvement and communication at the local levels, but conceptually as well. Both call for classroom changes that will require students to assume greater responsibility for what they learn. Both call for a more integrative understanding of science and mathematics and the role these disciplines play in helping us understand the world we live in.

Both initiatives also anticipate a different kind of learning environment. They require a classroom where students frequently work together in teams, where the teacher is more a facilitator than an instructor, where the use of computers and calculators is standard practice. This means teachers will have to master concepts from a variety of disciplines; abandon standard, traditional texts; understand how science and mathematics can be used to attack real world problems; be prepared to utilize new methods for assessing student performance; and be involved professionally in order to stay abreast of rapidly changing developments as the reform efforts evolve.

In my opinion, enabling our current and future teachers to develop the knowledge base and the new pedagogic skills necessary to implement the reform agenda is the greatest single challenge we face in improving science and mathematics education in our schools. Paradoxically, it seems to be the one issue that so far has attracted the least attention and effort on the reform agenda.

Implications of Educational Reform on the Preparation of Teachers

Before I discuss some of the implications of the reform initiatives on teacher preparation programs, I would like to describe a project led by Dr. Patricia Campbell, Associate Professor of Mathematics Education at the University of Maryland at College Park. For some years now, she has argued that the way to improve student performance in mathematics among traditionally low achieving elementary school students is to engage these students in mathematics throughout the day in practical, real-world situations. That is, to get them to think of mathematics as something that arises naturally in day-to-day situations, *not* as a discrete subject to be studied for a fixed period of time each day and then set aside until the next day.

In 1990, Maryland's Montgomery County public schools and the University of Maryland received a grant from the National Science Foundation for a collaborative project involving six elementary schools. The project, called Increasing the Mathematical Power of All Children and Teachers, or Project IMPACT, involves grades K-3 and focuses on schools with a high percentage of minority students, a high percentage of students from families receiving federal assistance, and a history of poor performance on a standardized third grade level mathematics exam. Three of the schools serve as intervention sites for the project and three as comparable sites.

Participating teachers at the intervention sites completed a twenty-two day enrichment course at the university. These teachers receive on-going support from mathematics specialists as well as specially prepared classroom materials. They also participate in a weekly group planning session.

Students in the experimental groups learn mathematics, in part, through discovery of mathematical phenomenon and the use of mathematics in practical settings. They are expected to explain to the teacher and their classmates the thought process they employ in doing their work. For example, the students might plot the level of rainfall each month and the daily high and low temperatures using data they collect from the newspaper. They would then compare the data with previous months and years and be asked to speculate on implications for fuel costs and food production during different periods of time.

A complete analysis of the performance of the experimental groups with the school as a whole and with the comparable groups is not yet complete. Personally, I have no doubt about the success of this approach. I have had a chance to watch several videos of the test groups at work in a classroom setting, and I was astounded at the level of performance. The picture of one African-American third grade student sticks in my mind. He was asked to multiply 72 times 6 without using paper and pencil. The expression on his face as he sat staring off into space thinking about the problem is still etched in my memory. After a few minutes he gave the answer 432, and the teacher said, "How did you arrive at that?"

He said, "Well you see, it's like this, 6 times 7 is 42. But you don't have 7 you have 70. So, you've got to add that 0. That gives you 420. But then you've got to worry about the 2 in 72. Now, 6 times 2 is 12 and the rest is easy." At this point, the audience I was watching the video with broke into spontaneous applause.

I give this example for two reasons. First, it shows that all the thought that is going into the reform effort can produce results. But there is a second point. We can expend enormous effort developing wonderful new curricula and standards, drawing on the talents of our most creative people, but all the effort will go for naught if we don't have teachers in the classrooms willing and able to deliver the new material using the current best thinking on learning strategies.

Many teachers were hesitant to participate in Project IMPACT because they did not feel comfortable with the level of mathematics skill the project required. This is an initiative for kindergarten through third grade. Imagine the resistance that will be felt in higher grades and with other disciplinary areas when more sophisticated strategies are developed for those settings.

This brings me to the final part of my talk: the changes we need to make in the preparation of teachers if the reform efforts are going to be successful. In addressing this topic, I want to say at the outset that the problem we face cannot, in all honesty, be laid at the door of our present K-12 teachers. Many of them are excellent teachers, fully capable of implementing the reform initiatives such as those recommended in Project 2061 or by NCTM. Many other current teachers, however, will have difficulty with the new curriculum and learning strategies, and will be resistant to the proposed changes. The failing is not with them but with our colleges and universities, and the kind of education we have offered those seeking careers as K-12 teachers.

Glenn Crosby, Professor of Chemistry at Washington State University, addressed this point rather directly in a recent publication of the National Academy of Sciences, entitled *Science Education Partnerships*. Professor Crosby said, "The way most universities are currently constituted, they are not suited to the task of educating teachers at any level."

His view, which I share, is that university education is too discipline-bound to produce the kind of broad, general knowledge one needs to be a successful teacher of science and mathematics, especially at the elementary and middle school levels. He points out that most chemistry departments in the nation aspire to provide a curriculum that is approved by the American Chemical Society, narrowly focused and designed for someone who is bound for industry or graduate school. The Chemical Society has recognized this problem and approved an optional chemistry/education degree. But to date, according to Professor Glenn, only one school in the country has adopted it. The problem recognized by Professor Glenn is not unique to chemistry. Indeed, I would say it's universal in higher education.

What, then, do we in higher education need to do to ensure that the students we prepare for careers as teachers have the skills necessary to carry out the reforms such as those proposed by Project 2061 and NCTM?

Fortunately for our nation, there are people far more knowledgeable than I on this topic who are giving this matter a lot of thought. One such group is the National Center for Teacher Learning based at Michigan State University. Under the leadership of Professor Jim Gallagher, the Center has been working on the issue of how we prepare teachers for an educational environment based on the 2061 reforms. Included among the principles the Center is considering are the following: teachers at all levels need an integrated knowledge of science and of how science leads to technological advance; they need to know about science in a social, historical, and philosophical context; and they need conceptual knowledge about science, not merely a mastery of technical vocabulary.

Beyond this kind of broad knowledge, they need new pedagogical skills. They need to know how to get students to raise questions based on observations, to encourage creativity, to promote a spirit of healthy skepticism. They need to develop in students a sense of responsibility for self-learning and an ability to explain clearly concepts that have been mastered. And they need to create learning environments where students work together and learn from each other.

This kind of teaching is not easy. Regrettably, it is a style of teaching that almost no university student is currently exposed to in science and mathematics courses. This fact must change. We have known for some time that people tend to teach as they were taught. A change in the learning environment along the lines I have just described would be valuable not just for future K-12 teachers, however. It would, in my view, improve the learning environment for all students taking science and mathematics courses.

In *Revitalizing Undergraduate Science: Why Some Things Work and Most Don't*, Sheila Tobias discusses some of her findings on the problems with the science education available to students, even at our best universities. Professor Tobias places much of the blame for the decline in interest in science and mathematics on the way we teach freshman and sophomore level courses in these disciplines. She makes a convincing case that the passive learning environment, where the student has no role in the lecture hall except as a scribe taking notes, is outmoded as a learning strategy.

If Sheila Tobias, the folks at the National Center for Teacher Learning, and others are right, and I think they are, the issue of K-12 science education reform is very quickly going to have to focus on universities and what they are doing to prepare the teachers who will carry out the reforms.

We are going to need new courses taught in new ways. Unless our universities commit themselves to developing and staffing these new courses, I fear our well meaning efforts at reform will make little difference.

But we need much more than new courses. We need new alliances. We need an alliance between colleges of education and colleges of arts and sciences, an alliance where people work cooperatively to develop the content and the pedagogy courses our prospective teachers will need to implement the reform curricula. This alliance also must work together to create classrooms where prospective teachers learn in an environment that models the environment in which they will teach. And this alliance must develop strategies to support the teachers in the early years of their teaching careers, strategies that address both disciplinary and pedagogical needs.

We also need an alliance between the universities and the K-12 sector to develop in-service programs geared to supporting the implementation of the reform agenda. In many states, the basic structure is already in place to provide effective in-service training.

Presently, however, we are using this structure to support teachers in areas that are irrelevant to the reform agenda. In-service programs should be refocused to provide teachers of science and mathematics at all levels with knowledge of content material and with new learning strategies. In-service programs also should assist experienced teachers in learning how to be effective mentors to new teachers.

We need alliances between superintendents and the schools to ensure that elementary and middle schools are adequately staffed by teachers with degrees in the sciences and mathematics and that these teachers are allowed to team teach so that in every grade students are taught by people knowledgeable in these disciplines.

And, finally, we need alliances between the schools and the students' parents so that parents can understand the objectives and the strategies of the reform movement and the role the home environment can play in the academic success of their children.

Fortunately, there is a new NSF program geared to developing the kind of pre-service and in-service programs that will produce teachers with the knowledge and expertise that will be required to implement the reform agenda. Last year, NSF established three national centers—one I am proud to say at the University of Maryland—for the collaborative preparation of elementary and middle school teachers of science and mathematics. Although this is a new program, I have been impressed by the enthusiasm for the effort among faculty both in our college of education and in our arts and sciences colleges.

As the work of these three national centers progresses and new centers are established, I believe we can begin to build the academic foundation on which a new system of teacher preparation and professional development can be built, a system that will support the successful implementation of the reform initiatives.

Conclusion

Our nation faces a formidable challenge if it hopes to significantly elevate the quality of science and mathematics education we offer our youth. Increasingly, I believe the responsibility for success in meeting this challenge will fall to our nation's colleges and universities.

Along with this responsibility, I believe we have a wonderful opportunity. As we all know, universities have come under considerable attack, even by academics themselves, for the low priority we give to our most basic responsibility—the education of students. Dr. Derek Bok, former President of Harvard, said it well in a recent address, "Until we convince the public, by our actions, that we indeed make education our top priority—that we are committed to the highest quality of undergraduate education—we will continue to be vulnerable to attacks on our curricula, our faculty, our tuitions, and all the different issues for which we have been taking punishment the last few years."

It is hard to imagine a better opportunity for American universities to reclaim some lost public trust than to become the champion of the educational reform movement in the K-12 schools. We must begin today the difficult work required to develop the curricula necessary for the preparation of tomorrow's teachers.

I do not for a minute underestimate the enormity of this proposed undertaking. But it is one worth doing, not just because it is vitally important for the future well being of our nation. It is also worth doing because it is only by reclaiming the teaching mission at our nation's universities—and this most definitely includes the education of our schools' teachers—that academe can recover its lost moral ground and restore some of its diminished credibility.

State Infrastructure Support For Science Education Reform

Alphonse Buccino

Talking about state infrastructure support for science education reform is a little daunting. Infrastructure, systems, or—heaven forbid—bureaucracies can be boring. Substantive issues, the things many others are addressing at this conference, are usually much more interesting and fun. Nevertheless, the topic is included in this conference because it is considered to be significant for science education reform today.

The significance of considering state infrastructure is derived from the notion of *systemic reform,* which is by now a well-established phrase in the discussion of educational change. It was introduced first in 1990 when the National Science Foundation brought out its program of Statewide Systemic Initiatives (Shields et al, 1994). Systemic reform is now a central feature of the Goals 2000 program discussed at this conference earlier today by Marshall Smith, Under Secretary of Education.

Systemic reform has its roots in concerns about elementary and secondary education that arose largely from international comparisons. Citing a series of five international studies conducted over the last twenty-five years, the National Center for Education Statistics (U.S. Department of Education, 1992, p. 29) reported that students from the United States generally lag behind many of their counterparts from other developed countries in mathematics and science achievement. There are a number of very significant technical problems associated with these studies that introduce errors and bias into the results. Nevertheless, the report emphasized that lagging U.S. performance is an important underlying theme of the studies.

The international comparisons led us to recognize that, as a nation, we do not have a very clear idea of what we want our students to know or be able to do. To address this issue, the President and the Nation's Governors met in their historic summit in 1989 to develop a set of National Education Goals, which they formally adopted in 1990.

The debate about National Education Goals was accompanied by discussions regarding the need to develop standards, world class standards in fact, to guide the implementation of the goals. At a crucial moment for national policy—and decision making—the National Council of Teachers of Mathematics (NCTM) published standards for curriculum and evaluation (1989) and for teaching (1991). These were widely praised from the outset and have become the model for standards development efforts that have been undertaken in several other areas. Although the NCTM effort was carried out without external support, federal agency support is being provided to produce analogous standards for science and other fields. The National Research Council (NRC), the operating arm of the National Academy of Sciences (NAS), is working on the curriculum, teaching, and assessment standards for science. The Academy's President, Bruce Alberts, discussed the effort this morning.

There now appears to be a clear national consensus that we need standards. Moreover, we need a system of national assessments to check on whether the students know these things and how well the schools are teaching them. This much is non-partisan. In fact, President Clinton played a leading role, as a governor, at the 1989 summit and led the effort for ratification by the governors. The goals have just been codified in March 1994 into national legislation called Goals 2000.

The Challenge of Systemic Reform

In 1990, *systemic reform* was introduced explicitly into this context. In defining its role to improve student performance in mathematics and science, the National Science Foundation (NSF) announced its program of Statewide Systemic Initiatives. NSF projected a vision of broad-based statewide coalitions to undertake ambitious, comprehensive, and coordinated reforms of the critical components of the systems of mathematics and science education. This new program is intended to transcend and integrate other NSF program efforts oriented toward individual components of the science education system such as development of new curricula or design of innovative approaches to teacher professional development (Shields et al, 1994). Attributes of systemic reform are:

- Long term
- Everything at once
- Involvement of all stakeholders

It appears, however, that systemic reform is becoming manifest in several forms. Systemic reform today is like re-building the house while you are living in it, or maybe like repairing your earthquake-damaged home while living in it, and contending with aftershocks. There is the triad of governance, finance, and politics that must be addressed if we are to seriously undertake systemic reform.

As regards *governance,* an interesting example is seen in Kiryas Joel, a village in the Catskill Mountains, fifty miles north of New York City. It was incorporated in 1977. The village and land are fully owned by a community of about 12,000 Satmar Hasidic Orthodox Jews. Over the years, a problem arose between Kiryas Joel residents and educators for the surrounding school about how best to provide educational services to the children with disabilities who live in Kiryas Joel.

To solve this governance problem, the New York legislature created a school district with boundaries identical to the village of Kiryas Joel in 1989. But the law has been challenged by the New York State School Boards Association as an unconstitutional concession to the demands of a religious group. In fact, oral arguments were just heard on March 30 by the U.S. Supreme Court. I bring this case up because I believe there is much more here than meets the eye. The extensive discussion of this case in the press reflects the complexity and interest the case holds (see *New York Times,* 1993 and *Education Week,* 1994).

What makes the case intriguing is that there are so many ways of looking at it. Colleagues in constitutional law tell me that this is not a clear-cut church/state issue and that there is a line of reasoning that could uphold the establishment of the Kiryas Joel School District. But if that were to happen, there would be an extraordinary proliferation of districts for similar religious reasons or for other reasons. Indeed, the Kiryas Joel case looks very much like an instance of school choice that is becoming an accepted and growing reality.

This brings into play the idea of cost. As desirable as it may be in our democratic society to encourage and support the proliferation of school districts and school choice, implementation of such proliferation is likely to increase significantly the cost of education. I doubt that our society is ready to pay the cost. Thus, school governance is closely tied to issues of school finance.

The school *finance* issue is underscored by what happened in Kentucky. In 1989, the Kentucky Supreme Court declared the entire state system of K-12 education to be unconstitutional. The case was based on a challenge to school finance and to differences among school districts in expenditures per pupil. The court found the whole system of finance to be incomprehensible and irrational and tossed it all out. The General Assembly was given nine months to rework the entire educational system and the task of implementing the new system is continuing today (Reidy, 1994).

The Kentucky case or cases similar to it are working their way through the courts in twenty-eight states and there is a strong likelihood that many of them may come to the same conclusion reached in Kentucky. In fact, the court has ruled against existing school funding formulas in thirteen of the cases. While upholding existing formulas in the other fifteen cases, several of the rulings were on grounds that allow for the cases to be reopened (Dayton, in press). In a way, this is like trying to sail on the sea of systemic reform without a ship.

So we see that school governance and school finance are under pressure. But that is not all. In addition to governance and finance, there is the politics of education to consider. The *politics* of education is the means through which we express directly and indirectly individual and societal expectations for education.

The politics of education has placed state departments of education under fire in many states. It seems sometimes that governors, legislatures, and citizens scorn their state education agency. Certainly, there is a trend to get state education agencies to be less regulatory and more facilitative. In some cases, there are overt efforts to bypass state education agencies altogether. There is an inconsistency about this because there are many statewide mandates that must be implemented, and it is not always clear how this is to be done if the state education agency is ignored.

While the role of state education agencies is in a state of flux, local education agencies are also under stress. Many reform programs proclaim the individual school as the element of change and the Charter Schools movement underscores this. Sometimes this leaves in question the role of the system. The idea seems to be to bypass both state and local system regulation. Moreover, it can be observed that public school choice is an accepted and growing reality for many parents and students even though its particular expression through vouchers has been soundly defeated in California, Colorado, and Oregon (Olson, 1993)

The impulse to bypass bureaucracy leads to some curious episodes. In one state recently, someone in the state education agency mailed checks directly to individual schools rather than to the district. Several principals returned the checks because they did not know what to do with them. The local school district is the legal entity empowered to enter into contracts, not the individual school.

The National Education Goals are also political in their nature and origin. We hear often the phrase "world class" in relation to the national goals and the standards we are developing for their implementation, but we do not talk much about the meaning of "world class" or cultural factors that affect the implementation of the goals. We do not talk about what I referred to earlier as "technical problems" associated with international comparisons which introduce errors and bias.

The length of the school day or the school year, is one example. Some of us believe that if America is really serious about, say, Goal 4, we are going to have to have our children attend school more days of the year than they now do and maybe for a longer day, too.

And there are other differences. America is the only nation that gives such unusual prominence to Euclidean geometry in the curriculum. In Denmark, there are no athletics in schools. There are robust athletic programs for young people, but they are community-based rather than school-based. Also, socialization is an important aim in American schools, but not in Japanese schools. Dating and social events such as dances are unheard of in schools of many nations other than the United States. In Japan, it is unheard of for students to have cars, and even riding a bicycle to school is discouraged (Stevenson and Stigler, 1992).

My point is that the heart of the idea of "system" in education involves the triad of governance, finance, and politics. This triad and its elements are in a state of change, which has generated confusion about who is in charge (governance), how we pay for education (finance), and what we are trying to achieve (politics). The resulting conflicts and contradictions makes systemic reform of science education challenging.

The Federal Establishment for Science and Technology

There is in Washington what might well be called a federal establishment for science and technology. Organizationally, this establishment includes the National Academy of Sciences and was represented at this conference this morning by its President, Bruce Alberts. The establishment also includes the White House Office of Science and Technology Policy, the congressional Office of Technology Assessment, the so-called scientific agencies like the National Science Foundation, the National Institutes of Health, the Department of Energy, the Department of Defense, the National Aeronautics and Space Administration.

This establishment, since its emergence in the post-World War II period, has always had a keen interest in science and mathematics education. The traditional rationale for this interest and for a federal role in mathematics and science education focuses on what is referred to as "the pipeline," the education system that produces and maintains the cadre of four million or so professional scientists and engineers who undergird the nation's scientific and technological endeavor.

The pipeline metaphor originates in *Science: The Endless Frontier,* although there it is called the "educational pyramid" (Bush,1945). This metaphor displays quite dramatically the tremendous attrition that occurs in the education system that produces scientists and engineers. Of four million high school sophomores in 1977, only about 200,000 earned science and engineering baccalaureates seven years later in 1984. Moreover, only 10,000 of those earned science and engineering doctorates eight years after that, in 1992.

The pipeline metaphor is predicated upon models of supply and demand for scientists and engineers. These models are no longer considered viable, and the pipeline metaphor is no longer considered suitable as a basis for policy regarding mathematics and science education. Also, the pipeline metaphor tends to generate a vision of science education as largely a matter of talent identification and development. But this has changed as well. Science education is no longer focused on just the talented. The present policy focus is on the mathematics and science education needs of the workforce and of the population as a whole. The new focus is not on the small number at the top of the pyramid, but the attrition and how to reduce it, so that larger numbers of our citizens reach higher levels of scientific achievement.

A number of agencies of the federal government support activities in mathematics and science education. The National Science Foundation and the U.S. Department of Education (USED) have broad legislative authority. The activities of other agencies are linked to the missions of the respective agencies in energy, space, defense, and health. On the science side, NSF is unquestionably the leader among the scientific agencies, if for no other reason than the large scope and size of the program relative to other agencies.

Until recently, these efforts were uncoordinated. However, during the last few years, the Office of Science and Technology Policy (OSTP) within the Executive Office of the President has developed a coordinated interagency program through the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET) with responsibility for interagency coordination of science and technology activities. FCCSET is a cabinet level council chaired by the President's Science Advisor and Director of OSTP. This interagency program plan is presented in the document called *Pathways to Excellence* (OSTP, 1993a). It was released on January 6, 1993, one of the last actions of the outgoing Bush Administration.

A summary of this interagency program is contained in a chart in the document titled: *"FY 1994 Federal Science, Mathematics, Engineering, and Technology Education Priority Framework."* The principle priority was:

Elementary and Secondary: Systemic Reform

- Curriculum, teaching, and assessment standards: development and implementation.
- State curriculum frameworks: development and implementation.
- Curriculum, course, and instructional materials: development and implementation.
- Teacher enhancement and preparation.

A little lower in priority one sees:

- Identify federal strategies to employ educational technologies more broadly.

Still lower:

- Promote formation and strengthening of partnerships between two-year institutions and other sectors.

This last is an indirect expression of concern regarding workforce education and training—technology education and technician training—which were seen as largely the province of two-year institutions.

So there is the priority: the National Education Goals, standards to implement them, curriculum frameworks in states that reflect the new standards, and materials and teacher education for operational implementation.

The Clinton administration moved the plan along, but introduced modifications. The first view of the new administration's direction appeared in the fall of 1993. This document was the FY 1994 Budget Document called *Investment in Our Future* to implement *Pathways to Excellence.* In budget terms, there was $2.3 billion requested in FY 1994 for the total program. Of this only 36 percent or about $848 million was for the top priority of elementary and secondary systemic reform. This reflects the fact that the science agencies also requested significant support for undergraduate and graduate education in accord with perceived needs related to their respective missions and reflecting the pipeline metaphor.

The $848 million for elementary and secondary education is largely accounted for by two agencies: NSF receives $353 million (or about 42 percent) while USED receives $343 million (or about 41 percent). The USED portion is all in the Eisenhower Mathematics and Science Education Program, which supports continuing professional development of teachers in mathematics and science content.

Although relatively small in dollar amount, the Department of

Energy program of about $45 million dollars is noteworthy. This program emphasizes using the scientific and technical resources of DOE's National Laboratories through such activities as research participation for K-12 science and mathematics teachers and students.

The budget document also pointed to certain shifts and redirection of the interagency program that the Clinton administration was introducing. First, FCCSET has been replaced by the National Science and Technology Council (NSTC). NSTC is chaired by the President, while FCCSET was chaired by the Director of OSTP. The Committee on Education and Human Resources (CEHR) that produced the interagency plan is now the Committee on Education and Training (CET). The new name reflects a new charge. CET now "accommodates technology in all areas of education as well as training."

Moreover, the focus has been expanded "from science education to include the rest of education and training" (OSTP, 1994). The situation today, as Marshall Smith has portrayed, completes the re-direction and quite clearly links the science education program to the Goals 2000 program. Science education has links to science and to education. The original interagency plan, I think it is fair to say, was strongly linked to science, but only weakly linked to *education*. The new configuration strengthens the link to education and gives a larger role to both the Department of Education and the Department of Labor.

These changes from the Bush to the Clinton administration reflect a long-standing contrast in American science and technology policy that goes back to the time of Thomas Jefferson. There is a tension between two different, but not necessarily opposite, forces or perspectives about science and the federal government's role to support science. This tension is suggested by the contrasting pairs of nouns such as elitism and populism, excellence and equity, and basic science and applied science. For science, this contrast is discussed by Daniel Kevles (1977) and for science education, by Philip Jackson (1983).

The Reagan/Bush administrations emphasized that the return on investment in basic research is hard to capture and, therefore, there are no incentives for the private sector to support it. Consequently, because an investment in basic research is essential for national well-being, the federal government must support it. This view is also embedded in *Science: The Endless Frontier.*

Others take a contrasting view, a view, incidently, quite similar to that of Thomas Jefferson. For example, in the view of Mr. George Brown, the Democratic Representative from California and the Chair of the House Science and Technology Committee, "support for basic research is justified only when more elemental needs of society are met" (Brown, 1993).

The shift from the Bush administration's *Pathways to Excellence* and FCCSET/CEHR to the Clinton administration's Goals 2000 and NSTC/CET reflects this same contrast. We might observe that as part of the dynamic of the contrast, the angle between them becomes wider or narrower from time to time, or there is a blending of the two perspectives. So, in addition to the turbulence I mentioned earlier in the governance- finance-politics triad, systemic reformers must adapt to this additional "political" shift in emphasis of science education in the direction of what I call the populist view.

State Structures for Science Education

We should note that, at the state level, there simply is nothing comparable to the federal establishment described above. There are state science academies, but they generally do not have the stature and influence of the National Academy. In large states like California, governors may have formally designated science advisors, but there are no agencies comparable to NSF or NASA or the Defense Department, owing to the national character of the mission of these agencies.

In Georgia, there is a Governor's Advisory Council for Science and Technology Development, and other states have similar bodies these days. But they are advisory, and do not have the operational scope that one finds in federal analogs.

Although science and mathematics education has been pronounced a major national concern, some states do not agree. For example, some states did not bother to apply for a Statewide Systemic Initiative project, and at least one state declined to do so because its governor did not think his state needed it.

The situation reminds me of a remark once made by a statesman of a Middle Eastern nation. He said that one has a problem only if one has a solution. If you don't have a solution, you don't have a problem; instead, you have a situation or a condition. Of course, this does not mean one does nothing. That's what I would like to get into now. There is no real solution, but there are some things we can do.

We certainly ought to be familiar with the educational governance structure of our respective states. There are four different models reflecting a somewhat different status among the governor, the chief state school officer, and the state board of education in state education governance (Education Commission of the States, 1993). At the state level, one needs to add the state legislature and the higher education system of the state.

Then there is the local tier of local school boards and local school superintendents and organizations of boards and superintendents. Organizations of teachers are also important structural components. Aside from state organizations affiliated with the National Education Association or the American Federation of Teachers, there are the state affiliates of the National Council of Teachers of Mathematics (NCTM) and the National Science Teachers Association (NSTA). Those interested in education reform must be attentive to all these groups.

But there are some new structural components that are also important, especially for science education reform. These new groups include the Goals 2000 Councils, the State Coalitions for Mathematics and Science Education, and the NSF Statewide Systemic Initiatives in the twenty-five states that have them. Working with these groups is an important strategy for prospective reformers.

But aside from formal structure, there has been change in the culture of governance including such things as an emphasis on deregulation and less bureaucracy, a focus on learning—in contrast to teaching—and a move to make schools accountable, in contrast to holding students accountable for their own learning.

Speaking of accountability, there is a dilemma embedded in it. I mentioned that there is a trend toward deregulation and reduced bureaucracy—which translates to greater autonomy down the line to the individual school and classroom. However, when accountability is invoked, it serves to re-establish the very regulation we seek to reduce and narrows the focus to higher test scores (Chubb, 1988). This is "behaviorism in a constructivist environment" and adds to the tensions and inconsistencies I have been pointing out (Reidy, 1994).

Now let me close with a discussion of challenges to scientists and science educators.

Standards-Based Education

We need to come to grips with standards-based education and support commitment to it and to its implementation. The central issue here is state and local implementation of the leadership coming from the federal government and expressed in Goals 2000 and *Pathways to Excellence,* modified as I have indicated.

Vision of the Achievable

The implicit and explicit message of both the Goals 2000 program and *Pathways to Excellence* is that science education is meant for all students and not just the few. For America and many other nations, the characteristic feature of formal education in this century is the provision of increased access. Over the last hundred years, increasingly larger proportions of our population have spent more and more time in schools and colleges. This is reflected in the expansion to nearly universal access to high school education in the early part of the century, followed by a great increase in access to higher education in mid-century. The phenomenon of increased access appears to have leveled off over the last twenty-five years or so and, as an issue, has been replaced by concern over outcomes and results. Specifically, how to help larger proportions of our citizens attain more from access to education, how to bring them to higher levels of achievement in knowledge and skill.

This shift in focus from access to outcomes is part of the contextual scene that led to the National Education Goals and to the standards movement. Thus, a major focus for scientists is the idea of elevating for all education professionals their "vision of the achievable" (Jackson, 1977) and strengthening their professional commitment to science for all.

This is not an easy task. My experience is that university scientists do not give high priority, to say the least, to those who might have difficulty with the subjects they teach. Moreover, it is my experience that university scientists do not have a deep belief in teaching. They may believe that there is such a thing as learning, but they do not believe that they can do much as teachers to help people learn science. This is an important challenge put squarely to university scientists—to clarify the vision of the achievable and to strengthen our commitment to it.

Teacher Education

Teacher education is a special challenge for undergraduate mathematics and science. To begin with, it is not that we have incompetence, but that our standards are broadening. A powerful trend in teacher certification and employment practices reinforces the call for a closer look at the content base for science teaching. Many science teachers are required to teach more than one science subject. School managers (i.e., principals and superintendents and their designees, who exert considerable influence in the selection of teachers) want as much flexibility as the managers of any organization. They want less regulation rather than more (Buccino, 1989).

As a result, one sees a major trend toward *broad field* certification for high school teachers in contrast to the traditional certification in specific fields of biology, chemistry, physics, etc. Two-thirds of the states certify science teachers through broad field as well as in specific fields. In Georgia, for example, certifying biology, physics, chemistry, or earth science *specialist* teachers is possible, but the certification of the *broad field* science teacher for all four subject areas is not only possible but the route preferred for teachers by school officials for reasons cited earlier. The broad field certification is the more prevalent route for science teachers and typically involves a major in one science field and significant academic work in the other fields. However, despite the fact that the total quantity of science study for broad field certification is substantial, there is no degree program in the university preparing the broad field teacher. A teacher candidate's course record frequently has much less coordination and integrity than is desirable and possible. This is a problem that is fully the responsibility of the content side of teacher education, the courses and programs offered by scientists.

For all of these reasons, there is a need for a *Science for All Science Teachers*, an analog to *Science for All Americans. Science for All Americans* is a comprehensive effort, sponsored by the American Association for the Advancement of Science, to have groups of mathematicians, scientists, and engineers define "the knowledge, skills, and habits of mind that all students should have acquired by the time they finish high school." This work is being used as part of the NRC effort to design standards for curricula in school science.

In the very same spirit, a major effort should be undertaken to have teams of mathematicians, scientists, engineers, and educators develop a *Science for All Science Teachers*. This development will then form the base for the design and development of programs for the preparation and continuing professional development of science teachers. The NCTM standards include standards for teaching as well as for curriculum and assessment in mathematics and were the basis for a subsequent effort by the Mathematical Association of America to develop and promulgate standards for teacher education in mathematics. This sort of work needs to be carried out for science. Moreover, both mathematics and science need models of exemplary programs based on these developments.

Educational Quality of the Workforce

A feature behind both the FCCSET/CEHR plan, and its revision to include Goals 2000 and the NSTC/CET plan, is the educational quality of the workforce. The relationship between education and work, especially education where the career or occupational endpoint is more clearly defined than for other areas is of growing concern. This results, in part, because much of the training of the workforce at the present time occurs after initial formal education is completed. The degree to which schools are preparing our young people with the knowledge and foundation required to find and hold jobs in the workforce of today and tomorrow has become a significant issue. Further, education and training over a lifetime have become increasingly important for maintaining the quality of the workforce. This issue has been extensively analyzed in several reports including Barley (1989), the Carnegie Commission (1990), the SCANS reports (1991, 1992), and Marshall and Tucker (1992).

This concern for the educational quality of the workforce arises from the fact of the enormous and continuing transformation we have seen and continue to see in the nature of work and the composition of the workforce, in terms of available and emerging jobs. Familiar to all is the great reduction in agricultural and blue-collar jobs and a corresponding increase in white-collar jobs since the turn of the century.

In this evolving workplace, the impact of technology has been felt in two very different ways. One impact is that technology has reduced the skill level needed for many jobs. The example often used here is that of the fast-food counter. Clerks punch buttons on the cash register identified by icons, so that neither reading nor basic arithmetic skill is needed. One can also argue that the productivity of marginally-educated workers has been increased by this technology.

But the other impact technology is having on work is more and more rapid commercialization of scientific knowledge, leading to new industries as well as dramatic changes in existing ones such as microelectronics, telecommunications, and digitized information. These impacts demand higher levels of *technical* knowledge and skill. The challenge to scientists and science educators is to do a better job in technology education and technician training.

Educational Technology

Two central features of the environment that make it especially urgent to reassess problems and needs with regards to education technology are: (a) the emergence of multimedia applications and (b) infrastructure for communication and networking. Regarding the latter, a major challenge for the federal government and the nation concerns the development of the electronic highways of the future. The National Information Infrastructure is now a central feature of the NSTC/CET program.

New Learning

New learning represents a departure from the notion of teaching as a process of transmitting information from the authority (teacher) to the learner. The student is, in this model, the clean slate on which new information is to be inscribed, or the empty vessel into which fresh knowledge is to be poured. But there is evidence that the clean slate and empty vessel metaphors are not accurate. In fact, we learn at all levels through some combination of communication from authority and personal exploration.

Contemporary thinking and research are providing important insights that indicate that students *construct* their own understanding and do not mirror simply what they are told or what they read. Moreover, the learner's formulation of understanding is based on a great deal of prior information. A child's cultural and familial environment affects how information transmitted in a classroom is processed in the child's mind. These environmental factors affect what is retained by the child, what is pursued further, and what is virtually ignored. Thus, students come to their science classes with surprisingly extensive theories about how the natural world works.

These naive theories affect what they perceive to be happening in the classroom and in laboratory experiments. These naive theories are developed as a natural human tendency to come to grips with, and find order in, a world that, especially to a child, seems incredibly complex. Moreover, they often continue to attach their incorrect and naive understandings to situations even after instruction supposedly provided correct versions.

For example, one piece of research showed that college students could successfully complete an introductory physics course, presumably having learned Newton's Laws of Motion, and yet persist in believing the contradictory Aristotelian "impetus" theory of motion, which holds that the capacity to initiate motion is inherent in an object, which in the absence of such initiative tends toward a normal state of rest. An excellent general reference on new learning is the book by Resnick and Klopfer (1989).

This conference is showcasing several perspectives on new learning, including the presentations by J. Myron Atkin, Jan Toumi, and Penny Moore this morning, and Peggy Carnahan and Gerry Consuegra as part of this session. Project SEED demonstrated at this conference is also an excellent example of how new learning might be implemented.

Moreover, new learning is embedded in the NCTM standards for mathematics education and the emerging science education standards of the National Research Council. It is interesting to note that new learning is also embedded in Goals 2000, which contains the statement:

> "The disproven theory that children must first learn basic skills before engaging in more complex tasks continues to dominate strategies for classroom instruction, resulting in emphasis on repetitive drill and practice at the expense of content-rich instruction, accelerated curricula and effective teaching to high standards."

But this viewpoint is stimulating controversy among scientists and science educators. Some believe that sound learning of science is hierarchical. One must progress carefully step by step up the ladder of skills and knowledge. Westheimer (1987) for example, has emphasized what he calls the vertical nature of the science curriculum and has asserted: "In science, you can't come in in the middle." However, others support the contrasting view that it is possible for students who are not yet sophisticated in quantitative reasoning to get a qualitative understanding of a model of complex phenomena that are too small or too abstract to experience directly in the "real world" (OSTP, 1993b)—what you might call the "relativity theory for poets" approach in some general education curricula.

What I call new learning is also referred to as the *constructivist* perspective. As is so often the case, the good news and bad news are the same. Constructivism, especially as presented here at this conference is certainly good news. It explains why students have trouble learning mathematics and science and helps us overcome the barriers. The bad news is that this same constructivism sometimes sounds like jargon and a kind of mysticism. There are also contrasting interpretations of the underlying phenomena (such as misconceptions) as, for example, in Subbotsky (1993). Moreover, while the demonstrations at this conference are impressive, they are far from a full school curriculum.

Despite these problems and issues, a major challenge to scientists who teach undergraduate courses is to model the new learning in their own teaching. The significance of this challenge is underscored by the reminder from theory (Bandura, 1973) of the truism that we teach as we are taught. I am convinced that new learning is the way to go and, in fact, the way we are going.

However, while new learning holds promise, traveling down that road is going to be very, very long and hard. To come full circle, new learning in its various forms—from phonics versus whole language to text/recitation versus inquiry oriented science—is a significant part of the environment that is keeping the basic structural triad of governance, finance, and politics so unstable.

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Helping Teachers Change Science Instruction

Gerard F. Consuegra

The two science objectives shown in Figure 1 are actual objectives from a real school system. While both support science, the programs they promote are significantly different. The first objective is traditional and is based on specific content related to astronomy and the solar system. The second objective does not support specific content; rather it identifies science processes to be taught and practiced by students.

Two Science Objectives

I. Identify the relative position of the planets to the sun
(Traditional 3rd Grade Objective)

II. Participate in identifying, organizing, and manipulating data
(Enlightened 3rd Grade Objective)

Figure 1

Another significant difference between the two objectives are the implied activities the teacher would use to conduct the science lessons. For the first, teachers would likely provide reading materials such as textbooks, library books, lists, and magazine articles. Additionally, the teacher might provide students with the information through lectures, class discussions, or small-group interactive sessions. Since the objective requires memorization, teachers might introduce a mnemonic device such as **M**y **V**ery **E**xcellent **M**other **J**ust **S**erved **U**s **N**ice **P**izzas. In many cases, teachers would encourage physical interaction by assigning students to build models of the solar system and its celestial objects complete with labels, orbits, surface colors, and somewhat relative sizes and distance relationships. When the instruction is complete and students are evaluated on their achievement, students are likely to be tested, assigned writing assignments, or perhaps asked to draw a diagram with labels.

Since the enlightened objective (Objective II) is not content based, the teacher is free to encourage an open-ended approach

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using materials that interest the students and are readily available. In this case, instruction involves activities where students collect data during a variety of investigations. These investigations might be found in textbooks or teacher's guides or they might be investigations that the teacher and students have identified based on their interest or curiosity (e.g., How long do banana peels take to attract fruit flies? How many seconds does it take for a hand lens to ignite black, green, red, and white paper?).

Following their investigations, children would likely be asked to look at their own data and make comparisons to the class data. As an aid to developing meaning for the data, students could be assigned to make charts and graphs and look for patterns and relationships. Guided by the instructional activities, assessment takes on a totally different approach. Students might be tested by reviewing a provided list of data and asked to organize and manipulate it. They might also be asked to conduct a similar investigation in which new data are generated and they are asked to demonstrate their ability to organize and manipulate the data.

Either way, this performance-type assessment is quite different from the pervious example involving students listing or describing the names and positions of planets. The enlightened approach promotes achievement of the objectives as well as requiring students to operate mentally at a higher level, engage in problem solving, and learn in an authentic environment that relates to the everyday world of children.

Shared Beliefs of the Science Community

Scientists and science educators jointly believe that science is important to society. This shared belief is expressed in the following statements:

"Science and technology are central to our personal and cultural welfare and to many societal problems." (NSTA position paper for Determining Effective Science Programs, 1982),

"Scientific literacy—which embraces literacy in science, mathematics, and technology—has emerged as a central goal of education." (Science for All Americans, 1989), and;

"Science and technology are powerful forces that shape human life on earth. They have enormous potential to make our lives better and richer, to keep our world safer and liveable, and to make our society productive and progressive." (What We Know About Science Teaching and Learning, 1993).

So strong are these beliefs that many educational and scientific organizations have issued reports and recommendations calling for systemic revisions to science education. Among those documents widely known are:

- *Science for All Americans: Project 2061*, (1989, AAAS)
- *Elementary School Science for the '90s* (1990, ASCD)
- *Promising Practices in Elementary School Science* (1993, Phi Delta Kappa)
- *EDTALK: What We Know About Science Teaching and Learning* (1993, Council for Educational Development and Research)
- *National Education Goals Report: Building the Best* (1993, National Education Goals Panel)
- *Benchmarks for Science Literacy* (1993, AAAS)

National Reforms

Collectively the documents listed above and the soon to be released National Science Education Standards (National Research Council) describe an enlightened view of science and science education. Such a view includes identifying key concepts, skills, and attitudes in science for the scientifically literate citizen, and describes effective instructional strategies, delineates characteristics of successful science programs for others to imitate and emulate, and lists resources for educators, scientists, and parents to use. The effects of these resources have been clearly visible over the past five years.

Nationally there has been increased funding for a variety of efforts such as research, curriculum development, training and planning institutes, and evaluation studies. Among prominent research efforts have been investigations of student misconceptions and techniques for confronting and addressing such misconceptions, factors that affect and promote the transferability of problem-solving skills, effective questioning techniques and the role of inquiry in science learning.

In an effort to provide up-to-date, accurate, and developmentally appropriate curricula, a number of curriculum development projects have been funded through the National Science Foundation and the National Academy of Sciences. Among the most notable elementary projects have been *An Insights Hands-on Inquiry Science Curriculum* (Education Development Center, Inc. and Optical Data Corporation), *Great Explorations in Math and Science–GEMS* (Lawrence Hall of Science, University of California, Berkeley), and the *Science and Technology for Children* series (National Science Resources Center and Carolina Biological Supply Company).

Training and planning institutes are helping school systems learn more about educational research, management techniques, new curriculum materials, and assessment techniques. Among such institutes are the NSRC Elementary School Science Leadership Institutes in which school districts send a team comprised of a superintendent, administrator, science supervisor, teacher, and scientist to develop district-wide plans for science curriculum reforms.

For districts that have begun their reform efforts, The National Science Foundation, Dow U.S.A., Hewlett-Packard Company, and other sponsors invited districts to participate in a Next Step Conference to explore issues such as systems management, staff development, and the intricacies of operating a science materials center.

Finally, a number of agencies such as the National Science Resources Center are offering leadership institutes for scientists and engineers modeled after school system leadership institutes. In these institutes, scientists learn about instructional strategies, mentoring techniques, and developmentally appropriate practices for working with children.

Finally, national organizations are engaging in evaluation studies designed to determine the status of science education and scientific knowledge in the United States. Most notably, efforts conducted by the International Assessment of Educational Progress regularly compare students in the United States with students from other countries, usually with disappointingly low scores for U.S. students. The Educational Testing Service also conducts national science achievement studies on a four-year cycle for students ages nine, thirteen, and seventeen.

Local Reforms

Locally, reform efforts are also underway including realignment of state science curriculum frameworks, outcomes, and indicators. These changes are serving as powerful stimuli for encouraging local school districts to do the same. As state and local revisions are implemented, administrators recognize the need for teacher training. Through Dwight D. Eisenhower Mathematics and Science Education Act funds, State Systemic Initiative projects, and National Science Foundation teacher enhancement grants, significant teacher training efforts are underway.

Nearly all such efforts recognize the complex nature of training and the variety of teachers' needs to be addressed. Consequently, these funded training efforts typically include content, pedagogy, and applications training, and occur over extended periods of time. Upon completing such training, teachers have a more comprehensive understanding of the basic science principles they are teaching. The effective instructional strategies are demonstrated, and clear ideas of how content and inquiry apply to their world and the world of children are provided.

Local boards of education and superintendents of schools are also recognizing that science is an expensive curriculum to implement, particularly using hands-on experiences and learning behaviors that emulate practicing scientists. Consequently, school systems are providing more funds for materials and equipment and successfully securing supportive grants from local scientific firms.

As school systems move to provide teachers with materials and seek to make the most efficient use of available funds, many are establishing science materials centers. Such centers loan teachers science material sets, usually science kits, on a rotating basis. These kits are then sent to other classes following replenishment of consumables, realizing significant cost savings through shared resources among schools.

Due to the centralized ordering system associated with science materials centers, school systems make better use of funds through bulk discount purchasing and original source purchasing rather than vendors. The result of such a system is that teachers have better access to necessary science materials and equipment, and school districts make the best use of limited funds.

What Has Changed?

Science educators have been formally and informally monitoring science education instruction since the national reform sparked by the launch of Sputnik in 1957. Although funding and interest has waxed and waned through the 1960s, 1970s, and 1980s, many scientists and educators have noted that science programming has shown improvement.

Today, teachers are better trained both at the pre-service and inservice levels. Teachers have improved curriculum materials using ideas from national curriculum development projects and responsive textbook publishers. Local districts are also responding by providing funds for science materials and equipment. More importantly, communities and school district leaders are supporting and demanding better science instruction.

However, despite improvements, science instruction is often still characterized by lectures and textbook exercises. For many teachers in too many schools, science instruction remains traditional when the teacher closes the classroom door and is alone with students.

Although there may be instances where teachers choose to remain hopelessly out-of-date and use antiquated materials and instructional approaches, many teachers would like to move toward an enlightened approach. After all, most teachers are highly professional and committed to making a difference for the nation's youth. Teachers are accomplished students in their own right, having learned how to learn and perform well on tests, comprehensive exams, and rigorous graduate papers. Teachers know what is expected of them and work hard to perform to those expectations. Unfortunately, teachers who would like to provide state-of-the-art science instruction often are prevented from doing so since they lack an infrastructure that promotes and supports such change.

Local Objectives and Teacher Evaluation

Instruction at all levels and in all areas is significantly influenced by local school system objectives. These objectives establish instructional foci for teachers. They define the content of instruction and, by their very nature, determine the instructional approach.

Objectives are powerful forces since teacher performance is evaluated based on whether or not teachers follow the prescribed curriculum, as determined by the objectives, and the number of objectives students master. Ultimately, teacher success is defined by how well students achieve or learn the content, processes, and skills listed in instructional objectives.

Earlier in this paper, two examples of objectives were analyzed to reveal the content, instructional activities, and assessment strategies they promoted. In one case, the traditional objective, the content is highly prescribed, and due to the language used, the activities were pointed and the assessment limited. The overall result is that the teacher is compelled to follow a traditional approach that follows the lecture, direct instruction, testing model.

The second example illustrates an enlightened approach where the content is deliberately not specified. Consequently, the teacher is free to design a highly customized set of activities to meet the teacher's knowledge, interest, and availability of materials as well as the interest of the students and applicability to their everyday world. In this case, the instruction that naturally follows is open-ended, problem solving oriented, inquiry-based, and consistent with the nature of scientific investigations as practiced by scientists and researchers. In many cases, student assessment becomes performance-based where children apply their newly developed skills and understandings. While both objectives require teachers to teach science, the resultant instruction is significantly different.

Enlightened Objectives

Teachers and scientists are thoroughly familiar with traditional objectives. Teachers have used them for years, and scientists

Science Process Objectives, Grade 2 and Grade 5

Montgomery County Public Schools, Rockville, Maryland

Grade 2

Asking Questions

2A1. Make predictions.
2A2. Participate in asking questions that are testable.

Communicating

2C1. Share collected data and other information by talking, drawing, charting, graphing, writing, and constructing models.

Gathering Data

2G1. Measure and compare using appropriate nonstandard and standard units.
2G2. Participate in planning an investigation in which one variable is changed.
2G3. Collect data over a period of time.

Making Sense of Data

2M1. Evaluate and revise inferences and conclusions.
2M2. Classify using given multiple criteria.
2M3. Identify cause and effect relationships.
2M4. Construct two and three dimensional models.

Grade 5

Asking Questions

5A1. Construct hypotheses.
5A2. Participate in modifying hypotheses.

Communicating

5C1. Use appropriate media to share evaluations of observations, procedures, data, inferences, and conclusions.
5C2. Participate in sharing evaluations of an investigation.

Gathering Data

5G1. Make and use operational definitions.
5G2. Use instruments to examine changes.
5G3. Participate in planning and conducting an investigation in which only one variable at a time is manipulated.
5G4. Collect data from repeated trials.

Making Sense of Data

5M1. Identify evidence that supports a hypothesis.
5M2. Use classification systems.
5M3. Participate in planning a classification system.

Figure 2

encounter them when they volunteer in classrooms or they are asked to review lesson plans, curriculum documents, and course outlines. Enlightened objectives are relatively rare, although they are occasionally found integrated among traditional objectives that comprise a science curriculum revision document. Unfortunately, the mere presence of traditional objectives inhibits teachers who wish to provide an inquiry-based problem-solving science program.

The elementary, pre-kindergarten through fifth grade, science objectives for Montgomery County Public Schools (MCPS), Rockville, Maryland, comprise a significant component of a state-of-the-art enlightened science curriculum. Following development over a three year period, with input from teachers under the direction of curriculum developers, the objectives have undergone substantive review by scientists, science educators, university and college professors, and state science supervisors. Additionally, the objectives comprised the curriculum component of a five year systemic teacher enhancement grant from the National Science Foundation.

The MCPS science objectives are process-based and are framed within four process strands: (1) Asking Questions, (2) Collecting Data, (3) Making Sense of Data, and (4) Communicating. Developmentally appropriate objective statements appear at each grade level and define the behaviors and thought processes that teachers are expected to promote. While students at all grade levels are required to learn and exhibit behaviors from all process strands, the specific behaviors at each grade level differ markedly.

Objectives at early childhood levels are cognitively less demanding and appropriately limited in abstract thought processes. Upper grade level objectives promote advanced investigative processes and abstract thoughts and modeling. Science Process objectives for two grade levels, second and fifth grades, appear in Figure 2.

With the support of a National Science Foundation teacher enhancement grant, teachers in MCPS are being provided with extensive science education training. In addition to science content, pedagogy, and application training, teachers are introduced to a new curriculum framework that contains the process objectives for their grade level. Part of the training includes a discussion of the principle "less is more" in which trainers tell teachers that they are being asked to teach fewer objectives in favor of in-depth understanding.

The reaction from teachers is universally positive. While teachers appreciate the apparent reduction in teaching load, they acknowledge the logic and developmental appropriateness of the objectives. Only later do they learn that teaching such open-ended objectives results in far more high-quality and intensive activities. Typically,

Elementary Science Units and Development Agencies

Montgomery County Public Schools, Rockville, Maryland

Grade	Title	Developer	Length
Pre-K	Underground Connection	MCPS	3-8 wks
	Play It, Weigh It, Say It	MCPS	4-6 wks
Kindergarten	Myself and Others/Senses	EDC	12-14 wks
	Balls and Ramps	EDC	9 weeks
	Living Things	EDC	9 weeks
First	Rocks, Sand, and Soil	CP	9 weeks
	Observing an Aquarium	DE	9 weeks
	Constructions	CP	9 weeks
	Weather and Me	NSRC	9 weeks
Second	Life Cycle of Butterflies	NSRC	4-6 wks
	Liquids/Involving Dissolving	LHS GEMS	4-6 wks
	Balancing and Weighing	NSRC	4-6 wks
	Habitats	EDC	6-8 wks
Third	Plant Growth and Development	NSRC	9 weeks
	Sounds	NSRC	9 weeks
	Crime Lab Chemistry/Fingerprinting	LHS GEMS	6-8 wks
	The Pillbug Project	NSTA	6-8 wks
Fourth	Earth Materials	LHS FOSS	9 weeks
	Electric Circuits	NSRC	9 weeks
	Mysterious Powder	EDC	9 weeks
	Ecosystems	NSRC	9 weeks
Fifth	Solar Energy	LHS FOSS	9 weeks
	Structures	EDC	9 weeks
	Magnets and Motors	EDC	9 weeks

Key:

CP – Creative Publications: Windows on Primary Science Series
DE – Delta Education: Delta Science Modules
LHS FOSS – Lawrence Hall of Science: Full Option Science System
EDC – Education Development Center: Insights Series
LHS GEMS – Lawrence Hall of Science: Great Explorations in Math and Science Series
MCPS – Montgomery County Public Schools
NSRC – National Science Resources Center: Science & Technology for Children Series

Figure 3

teachers report that the resultant instruction they provide is more comprehensive than their former traditional program.

The consequences of such a process-based curriculum are highly beneficial to all teachers. Experience has demonstrated that good science teachers, ones that are naturally inclined to provide an enhanced science program, use these objectives to validate their open ended and inquiry-based activities. Traditional teachers, who are expected to follow the science process objectives and evaluated on their ability to deliver such a program, are compelled to provide an enlightened science program. In both cases, the science process objectives promote an enlightened, up-to-date science program.

The Role of Science Content

While a science process curriculum may be consistent with the investigative approach exhibited by practicing scientists, skeptics often point out that there is no science without knowledge. Such individuals use this approach to push for a content-based curriculum. The MCPS curriculum addresses this issue by training teachers on two to four nationally developed science units that contain rigorous science content in a context that promotes inquiry and investigations. Figure 3 lists the units at each grade level and cites the development agencies for each. During the training teachers receive, they are told that they are expected to teach the content of the units within the context of the science process objectives for their grade level. Since the units are exemplary and consistent with real science and significant content, teachers report that their students learn more content than through traditional approaches and, simultaneously, have ongoing opportunities to ask their own questions, investigate problems and issues that interest them, collect data to answer their own questions, and have many opportunities to communicate their understanding of content and process using a wide variety of media.

In a third grade example, consider the following objective: "Collect data using a variety of instruments." Teachers support this objective by teaching the unit *Plant Growth and Development* (National Science Resources Center, 1991). During the unit, students measure the growth of Wisconsin Fast Plant *(Brassica)* and learn about germination, growth spurts, and pollination.

In the fifth grade, when teachers support the objective "Identify evidence that supports a hypothesis," they use the unit *Solar Energy* (Lawrence Hall of Science, 1992). Students explore solar collectors and design effective prototypes for further investigations. Consequently, students learn about heat sinks, the effects of the sun's angle of incidence on solar energy collection, and insulators and their properties. In an unobtrusive way, teachers are engaging children in learning significant content as they learn to behave as real scientists.

Concluding Remarks

While scientists, administrators, and teachers are committed to improved science instruction, the process of systemic change is a complex and ongoing project. Experience has demonstrated that teachers are willing to implement an up-to-date and inquiry-based science program, but they need an infrastructure to support their efforts.

While many factors contribute to the desired outcome of enhanced science, none are more significant than the objectives provided by a school system. Science process-based objectives provide infrastructure and promote modern and traditional science teachers' efforts to provide science programming that supports scientific literacy needed for the 21st century.

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1994 McGovern Lecture for Sigma Xi

Nothing is Too Wonderful to be True

Philip Morrison

Truth and Fiction

This time of ours is brimming with plausible and attractive fiction, special effects, dramatic advocacy replacing well-weighed evidence, beliefs held because they appeal—all of these stream past us in a torrent of images and of fluent words. (Recall the ignitor that certain TV investigative reporters added to make sure that in their simulated truck collision test the gasoline would catch fire in front of the cameras, a style not wholly new, and probably not carried out then for the last time.)

Here is a major public issue. If we do not find some way to improve the level of public discourse beyond this present high temperature, if we do not find some way to temper drama, exaggeration, advocacy beyond the facts, even unto hyperbole, democracy cannot for a long time endure. There has to be a typical suspension of final judgment, an appeal to weigh the evidence, to seek more, and to reflect: fit subject matter for a McGovern Lecture on Science and Society. In that spirit I proceed.

For me the concrete supports a presentation by a scientist better than can any wholly abstract discourse.

I shall therefore outline three little tales, each of which is wonderful, each one of which draws close to the truth. In science we do not often lay claim to final and absolute Truth, but only to those working lower-case truths of the real world: ginger is hot in the mouth, the earth is more or less a sphere, we humans are all cousins—more than that, we are at least distant cousins to that frog in the grass, and even to the green blades.

All three topics represent different styles of gaining knowledge, different processes for the pursuit of scientific research, yet all are part of science and of the teaching of science. I hope you will see them as instances, not at all as exhausting the matter. They are only pointers to what you yourself may note and discuss in utterly different cases as time goes by.

Extending the Senses

The first instance, and the grandest, strikes a theme implicit in most scientific work, if one too little apparent to the general public, too little grasped even by science students. We don't understand well enough how to make this theme clear, although it should be manifest, for it is also the essence of TV, radio, and e-mail, now so pervasive. Yet almost nobody thinks of that fact.

Those complex and remote media appear somehow transparent to their users. You imagine almost that you are only looking through a simple glass window into the TV studio, or that on the screen you see your friend's keystrokes in Poughkeepsie.

We all know that's not the case. There is an elaborate and contingent structure between transmission and reception. That has to work. The trouble is that it's been made so well, engineered so beautifully, works so much of the time, that most people give up understanding it, give up thinking of it as in fact anything of an intermediary. They don't think of the content they get as at all contingent, at all limited by the technology and the sender. It's the way it has to be; if it isn't that way, well, something outside all experience is wrong: shrug your shoulders and wait for a better day or for the repairman.

But all these new media are in fact profoundly extended human perception. We see the invisible, hear the inaudible, reach back in time or even far forward in thought. Such actions are part and parcel of the natural sciences (even the historical ones); they are of extraordinary importance to those sciences. For me, they part science as a whole from two other grand systems of thought and action that seek to order the world: the work of the philosopher, and the work of the artist. The work of the philosopher (almost entirely linguistic, plus some mathematics) does not extend perception. It takes what's given and orders it, or merely postulates behind it what is not perceivable. The work of the artist generally tries to order the world in a new way, but it depends instead very strongly upon human perception. Though art does include the linguistic arts of literature and poetry, few indeed are the works of art that are made to be viewed only by microscope or only by X-ray. Artists work for an audience that can come to their art with no instrumentation past the inborn and well-tested senses.

My first example is a startling truth, probably of great importance to the structure of the cosmos itself, yet one we can perceive only after a truly heroic extension of the senses.

Inference

Example two is much simpler. I intend to draw a simple inference from a great deal of painstaking detail that scholars and scientists and tireless, fortunate explorers have long laid before us. Can we take those facts and from them draw one probable inference? This is a technique quite familiar in the detective story; it is also an important part of the procedure of science, especially of those sciences less instrumentally based than physics or astrophysics.

Participation

My third instance is from that best of all teaching modes, where I ought to have begun. I will end there instead, direct participation in one simple educational activity, one I have seen used for in-service teacher training at Harvard University.

Example 1: Radiant Matter

For the first case, I must talk about an amazing phenomenon, what I will call "radiant matter." (That's a phrase of my own, with which I hope to soften the technical jargon at least a little.)

Any of you who has read much physics, especially the newsworthy popular physics of our day, recognizes the neutrino. The neutrino—the term means "little neutral one" in Enrico Fermi's language—is something akin to the electron, that ubiquitous constituent of all matter from your own eyelids to the stars of the Big Dipper. But instead of the property we call electric charge, so characteristic in that it implies strong electron response to electric and magnetic force fields, the neutrino knows no such urges. It ignores those famous forces; it responds only to gravitation except when it is in intimate contact with nuclear matter. Its interactions with all material particles on close contact is extremely weak, amazingly rare, incredibly improbable. Never is it found bound within matter as almost all electrons are found.

Yes, there are radiant electrons as well. You can boil them out of hot matter in a TV picture tube, and out they stream in a beam that flies free in the vacuum. (Normally we think of electrons in a much more passive and homely context, simply bound into your hand or any other material object.) Every atom has its full charge of electrons, give or take some atoms in the state we call ionization, either lacking in electrons or replete with a few excess electrons, like the atoms of sodium and chlorine bound into simple salt and held close together there by electrical forces.

I can't go through the narrative in all detail, but I think I can suggest enough to show the very striking consequences during the last few years, all but too wonderful to be true!

The prehistory goes back to the great year 1895; physicists are rather poor at dates; for us, the twentieth century began then, a few years early. It opened with the finding of X-rays, radioactivity, and within a year or two, the electron. All those came to first sight about then. The prehistory of the new radiant matter, of the neutrino, is the initial work of Henri Becquerel and also the more famous and mature work of the great pair of radioactivity, Marie and Pierre Curie. Their work burst on the world at the dawn of the twentieth century. For forty years, they and a couple of hundred others in many countries worked out what even people who don't know detail have often heard about in words: alpha, beta, and gamma rays, the radioactive emissions. That's what the pioneers found. Lots of detailed ordering went on, even though it was very early in the atomic day, even though quantum theory itself was in a primordial, approximate, and very incomplete state. It was enough to guide the work, and many brilliant things were found. The whole wonders of radioactivity go back to that time, before and during World War I, laying the foundation of the fateful physics of nuclear fission in World War II.

One deep puzzle was left. It reached its most enigmatic form in the years 1925 and 1926, when no less a clear thinker than Niels Bohr abandoned the overarching energy principle, the general result of all physics, that energy cannot be gained or lost. Energy, Bohr felt then, did not seem to be conserved in each individual atomic event; that law might, he said, hold only on the average for large-scale change, but not atom by atom or photon by photon individually.

That was the enigma presented by what they did not then know—the neutrino. To abandon energy conservation was a physicist's calamity. It was avoided: within a year or two, many experiments were done in the atomic domain to show that, in fact, energy was always conserved. In every set of distinct events they could find, energy was conserved, not only in the average, but in each individual transaction, in each individual atomic event. When any single photon disappears, its full energy reappears in some atom (and vice versa).

The demonstrations were prompt and powerful; soon Bohr retracted. But he was not satisfied until we solved the puzzle that was posed by what we call the neutrino.

The wonderful solution of this enigma began a few years later, in 1930. A famous letter, (alas, I have no time to read it) was written by a young and brilliant theorist in Zurich to a group of German radioactivity specialists meeting in Tubingen. The letter opened: "Dear radioactive ladies and gentlemen . . ." (Lise Meitner was then the most celebrated expert in Germany.) It was Wolfgang Pauli who wrote the letter in apology for missing the small meeting, because he had to attend the Italian students' ball at his university! He wrote "I would like to propose a desperate remedy" to the problem of the lack of energy conservation in the well-studied case of radioactive beta decay, the sharpest example of Bohr's troubles.

Pauli's proposal was made confusedly; its key idea was original and proved absolutely correct, though many details were still misunderstood. What he said was this: Something very strange is found in this particular class of radioactive atomic decay. The other sorts of radioactive change—alpha and gamma decay—were perfectly understandable under the simplest quantum rules. Beta decay never seemed to show the energy expected, but always too little.

The reason, he said, is very simple. We think of beta decay as being the emission by the atomic nucleus of one single electron. That's all you find with any detector, and the nucleus changes by losing one electron. But, said he, suppose an invisible twin particle comes out along with each electron. (Later it was named a neutrino by Fermi, who understood the events much better in a year or so than Pauli had in his first suggestion.) Those two particles fly out of the atom simultaneously. They share between them the whole energy that is taken away, just the amount of energy that the quantum theory expected. But you catch only one of the two particles, the electron, because it readily interacts with the electrical particles within ordinary matter, mostly other electrons. That new-made fast electron gives up energy over many atomic collisions until finally it stops, caught in your detector and recorded. The rest of the energy goes off with the free-flying neutrino. It leaves your apparatus, indeed, leaves the earth as a whole, flying out to free space, thus only apparently violating the conservation law. It's out there, still with its own kinetic energy of motion, just what it ought to be (the rest of what the atom lost but that the electron didn't take), yet forever missing from your most meticulous energy audit.

Fermi took up Pauli's idea and made it work quantitatively, first in 1933-34. He was daring, because he had postulated a new particle, a new kind of matter no one had ever detected, just to solve the beta-decay energy puzzle. Nowadays we know of many particles alien to normal matter, but the neutrino was the first of them. From then on for twenty years, all of the phenomena of beta radioactivity—the lifetime of the decaying atoms, the distribution in speed (and hence energy) of the electrons that you could measure, and many other confirming atomic details dear to the experts—could all be rationalized beautifully under Fermi's brilliant theory.

I hope that you have a little of the feeling many physicists had in those years. There's a little bit of a swindle here! To say that Fermi can describe simply what happens when energy disappears is one thing; but to say that energy is really conserved because his little, invisible neutrino has taken it away is not yet the same thing. There has to be some closure possible. If that elusive neutrino is really a little particle like any other, we should somehow or other be able to catch it to fulfill the energy balance. Otherwise, you're just saying that energy disappears, though in a relatively simple way. That's quite nice, but it doesn't really allow the conservation of energy to remain a pillar of the theory. The solution is rather verbal.

It took a generation to complete the closure. A few brave people (especially Fred Reines and Clyde Cowan, working in Los Alamos in the fifties) said, "We will catch the flying neutrino to see if it in fact carries the missing energy far away." How could they catch it?

They could catch it only because in their time the one gram of radioactive radium that had been a radioactive source of world class power for Marie Curie or Ernest Rutherford or Lise Meitner over a span of fifty years had now become effectively a hundred tons of radium that was decaying within the huge nuclear reactor in Savannah. (It's not exactly the same, but it is really quite comparable to that bulk of radium.) One could estimate that about the same number of invisible radiant matter particles, the neutrinos, were flying out as would come from all that massive radioactivity, at pre-war prices a cool trillion dollars worth! The contractors had provided a magnificent shield, fifty feet of concrete and steel, so that no substantial number of interacting particles of the ordinary sort—no electrons, no protons, no neutrons, no gamma rays—would get through the shield into the apparatus or the bodies of the crew at work around the reactor. Next, instead of using a small Geiger counter filled with gas and about the size of a fountain pen, which is what people thought in 1935 a pretty good instrument for detecting particles, they had tons of water as a detector and a very clever scheme to look for very weak light made by the interaction of some neutrinos in the water.

Of course, every particle made has to be able to be caught again, in principle. One of the most powerful propositions we have is the reversibility of specific interactions. If it is made in matter it must be possible to catch it again by the very inverse process using the same sort of matter.

The trouble is a neutrino cannot reach out as do the electric forces to affect something far away. It must come into contact. We're familiar with contact forces on large scale. But what the neutrino must contact is a proton or a neutron. A proton is tiny. Therefore, as the neutrino flies with nearly the speed of light in a straight line through matter, it goes through atom after atom, until by chance it directly strikes a central proton. But how long will it stay in the near neighborhood of that proton? At the speed of light, it passes out of contact in a very short time. It can never spend much time inside the nucleus.

It turns out that it takes an understandable amount of time, like a millisecond or maybe a second, depending on the circumstances, for a neutrino to be picked up by a nuclear proton. When it is absorbed by a proton that it enters, it simply doesn't leave again. The neutrino disappears. In its place appears a positron, and the proton is changed to a neutron. Energy is strictly conserved. We do see it happen rarely.

But on each near approach to the proton it is in contact for nothing like a millisecond. It passes by—if I use the powers of ten notation—within only 10^{-21} or 10^{-22} seconds. How then can the capture ever happen? Well, that's why people thought it would never be observed because the event is too rare. Neutrinos would be able to go through light years of solid iron before that wall would catch fifty percent of them. There's no such thing as light years of matter, not light years of mere space, but light years filled by solid matter. A giant star is crossed in a few minutes. Catching neutrinos seems out of the question.

Yet recall that it's all a lottery! Neither neutrino nor proton know whether the first proton, the second proton, or the 10^{22nd} proton is going to interact. The neutrino is simply exposed to the same tiny risk over and over again. The event can happen any time a proton is close by. Well, how can you make it happen under your eyes? You can't pile up iron light years thick to stop the beam.

But there is always one way to win a fair lottery. Buy huge numbers of tickets. You can't guarantee to win until you buy them all, but if you buy enough tickets you have a good chance to win. So first you prepare a large detector, many many protons, many tons of water. That means you buy many tickets for detection. Then you find a huge source of neutrinos, an enormous stream of radiant neutrinos passing through your detector. All are equally—but each one only very slightly—at risk, vulnerable. Once in a while, inexorably by the laws of chance, you must expect one neutrino to be caught somewhere. Among all your protons, one of very many almost instantaneous encounters will suddenly prove to be terminal. The neutrino was gone, its energy absorbed in the necessary particle products.

What you must do is watch as many atoms as you can. Get a big sample and watch them all carefully. Some fine day you'll catch one out of the neutrino torrent. Of course, for every one you catch you can infer for sure that a great many more have passed by untouched. That's exactly the situation with radiant matter, the neutrinos. That happened first in 1959 in South Carolina, and the happy and patient experimenters cabled the now elderly Pauli to say that they had at last caught his postulated neutrino. Of course they kept their peace until they had caught enough of them to be quite sure. Any one or two events might be mere noise in the detectors. They had hundreds.

Thirty years later, a cosmic event in a remote star took neutrino physics by storm. In the southern sky is the striking Tarantula Nebula. Near it there appeared to the unaided eye on the night of February 23, 1987, a new star, never before seen, now faded away again except in the very largest telescopes. It is a supernova, the closest one seen for centuries, though far away, within that little satellite galaxy to our Milky Way we call the Large Cloud of Magellan.

Hours before the new star was first noticed by Ian Shelton at the European Southern Observatory, something unique had happened. The theorists had come to believe that there might be occasions when a supernova would release a vast burst of neutrinos, and they had convinced the experimental physicists to build and maintain giant neutrino detectors. (In fact, these expensive things were built for another even more important research goal, but I don't want to go into that. That effort did not succeed. But the million-dollar detectors could be converted to look patiently for neutrinos. Fortune was wonderfully kind; they waited only a few years.)

The neutrino detectors alone made the amazing phenomenon perceptible. No other way we know could have disclosed what they found then, at about 2:00 a.m. EST on February 23, 1987. One detector is a thousand feet deep under the lake shore in a salt mine of the Morton Salt Company, about thirty miles from Cleveland. It occupies a rocky chamber the size of a modest six-story apartment building. The chamber is lined with a watertight plastic container, full of very clear water, through which light can easily travel for tens of yards. Its walls are lined with a couple of thousand very classy video camera tubes: not cheap, but there they are. They are not ordinary TV cameras because they are capable of recording, within the computer that tends and watches them, exactly when photons of light arrive, to within some tens of nanoseconds. The second detector, a counterpart, is across the world.

Why were they built so laboriously down in the mines? On the surface of the earth, the cosmic rays are so numerous that they make all kinds of random light pulses in the tank; your detector is overwhelmed. But put it down in the mine. Few cosmic rays penetrate so deep; true, some are there still, but by comparison the mine is well shielded. Purify the water for six months, running it, running it, running it, until it becomes purer and purer and purer through wonderful chemical filters, eliminating all the radioactive atoms caused by cosmic rays when it was at the surface, and you have a chance to look for rare neutrinos.

Be patient, and you may see something quite wonderful in the computer records. The computer will map the pattern of the light that falls with each event on some dozen of the thousand phototubes on the walls of the chamber. You can triangulate where the neutrino died, to give its energy to a particle that can spend much of its energy in a quick burst of photons. You have caught a neutrino by inference, if all is working as planned.

There were two such detectors. One was in Ohio, and the other, made under similar principles but with a different computer, different algorithms, different physicists planning and building it, different video cameras, everything somewhat different, was located deep in the Japanese Alps in a zinc-copper mine, half way around the world from Freeport, Ohio. At the same second on that morning of February 23rd, both of these detectors reported a burst of a few neutrinos. Had only one reported it, most people (I too) would have said quite skeptically, "Interesting, but probably something wrong with the computer. It gave you that signal, but how can you be sure there was something really there?" But if two places find the signal independently, it's very hard to doubt. That never happened before, and never happened since. Between the two of them, only nineteen detections—eleven in one place and eight in the other—were seen, but never had any such multiple count come within a fraction of a second. Normally, they saw only one false event every few tens of seconds. Now instead of a random slow tapping, both mines noted the same swift rattle of counts. The counts came with the visible supernova, as prediction had said. We are all convinced. Fifty or a hundred papers have analyzed these data, and there seems little doubt that a flood of neutrinos came by that few seconds from the distant Magellanic Cloud.

The most amazing point I must emphasize again. The cloud of stars where the supernova is seen is ten billion times farther away than the sun! The star grew quite bright to the eye, but nothing, nothing like as "bright" as it was in neutrino radiation. In neutrinos, it was radiating out for that second more energy in neutrinos than all the light sent out normally in one second from all the stars in all the galaxies in the entire universe of stars. One collapsed star, for that moment when it was at its maximum, gave even to the surface of distant Earth a tremendous burst of neutrino energy. Those neutrinos even had to pass through the whole bulge of planet Earth to pass straight from the southern sky to Ohio and to Japan. No problem! If most of them could penetrate light years of matter, then the tiny earth, not even a tenth of a light second thick, will not remove them.

We are able to say the supernova produced in that moment as much energy flow on the surface of the earth as normal sunshine does daily on Earth's surface, although this radiance came from a dying star ten billion times farther. That sunshine flood of energy went entirely unsensed by any human beings, by any animals. Only the big detectors reacted. Of course in the depths of the earth some nuclear particles did react. We'll never find those few million atoms throughout the earth. But in the detectors, where we can watch the origin of each consequent flash of light, they could count a tiny sample and infer the whole. You don't get so many neutrinos until a nearby supernova appears, an event we expect only once in a few centuries, so it was really a very lucky affair.

That story leads to a conclusion we can no longer doubt. All through space there flows radiant matter—that is to say, our star-born neutrinos—with about the same amount of total energy as all the steady starlight from all the stars in all the galaxies. These star collapses in galaxy after galaxy are rather uncommon, so their explosive neutrino output doesn't enormously exceed the steady optical total. But as it happens repeatedly the radiant matter fills the whole universe, overall at least as important in energy terms as starlight. (My calculations suggest that the unseen neutrinos are several times greater in total energy than all the starlight in the universe.)

Now, we've never detected that powerful flow. You can't see it. There are no sensory organs evolved to detect it. This is a triumph of the imperceptible, of the extended senses. It leads easily to a still tentative conjecture, which in the last three years or so has taken stronger and stronger form. Such radiant matter, such neutrinos (or other known varieties akin though perhaps not identical to them) may by its overall gravitational effect control the distribution of all ordinary matter in this our universe. Its gravitational pull may form the superclusters and the clusters of galaxies, indeed all the visible material, all the atoms of which we and the stars are all made.

What we are and what we can see may be only an impurity of the major actor in the gravitating universe, the invisible, indifferent, but teeming neutrinos. We don't know that for sure; one key fact is still missing. We don't yet know whether each individual neutrino has enough mass to provide the overall gravitational effect we surmise. If that invisible gravitating matter is not neutrinos, it's something even stranger that we can so far hardly describe at all.

In thirty years the neutrino came from an unseen obscure puzzle to a good candidate for most of the matter in the cosmos! To me that makes clear how urgently we depend upon extended perception. To me, it also makes clear how hard it was for physicists to accept this radiant matter. They first had to understand what was going on in beta decay. Then they doubted a particle that couldn't be caught. Then they found how to catch it. In fact, in the great laboratories, they now make and use beams of neutrinos routinely. True, the neutrinos made in the big accelerator laboratories are easier to catch than those of the cosmos, because they have higher individual energy and so they interact a billionfold more frequently. In the labs a billion or ten billion neutrinos are made in one flash, and you may catch just one of them every few seconds down a long tunnel blocked by rock and steel shielding.

For the supernova we caught far fewer. The number of neutrinos that came up those few seconds through the bottom of those pools of water in the mines—a once-in-a-lifetime event—is of the order of a billion billion; we caught only a dozen or two of them in our little pools. Of course, if the interaction had occurred in the earth below, we do not see it. Yet the supernova neutrinos still spread out to flood through all of space.

Let me say something else to make these results both homelier and more wonderful. I have pictured the neutrinos as alien to everyday life as they possibly can be. Yet they are not completely alien, for we too are a part of the natural world; it works its ways in us as well. Maybe a hundred thousand persons on Earth who don't know it experienced a track of ions within the body from a star-born neutrino. It caused a fast positron to be formed, to move a few centimeters in the body, losing its energy until it stopped. No cause for alarm: it happens with cosmic rays a thousand times a minute to everyone everywhere, here on the surface of the earth. But for those persons one single energy-loss event was occasioned by a supernova neutrino from a remote star in collapse. We'll never know just who.

More intimately still, a few neutrinos are made on the earth in the steady beta decay of radioactive atoms. They don't stay on hand, but spread radiantly into space. I have to tell you that you (like any ordinary person of average weight in all human history) are producing now, this very second, some two hundred neutrinos per second from the decay of a rare naturally- radioactive isotope, potassium-40, found in the intercellular fluids of all forms of life (and in rock and in seawater) as it has been since life began. You are radiating to your neighbors a few hundred neutrinos per second. Don't worry. The sun is doing very much more than that by day and by night.

That imperceptible radiant matter may possibly account for most of the mass in the entire universe; surely that would be a find all but too wonderful to be true!

I emphasize that this account depends upon two things: the physicists' uncanny ability to extend the senses, and their willingness to be critical, to test and try again, to let no stone go unturned, to do everything they can to make sure that what they are saying is not nonsense. I don't believe it is deniable. In Japan and in Ohio the same well-defined events came at the same moment—when it has not happened before for years, nor happened since for years—and along with them came the extraordinary supernova, all details as roughly predicted. Such evidence is hard to doubt.

Example 2: The Old World and the New

Let me proceed to a quite distinct story. This story depends not on one remarkable event, but on rich if circumstantial evidence, accumulated in large numbers of finds in many places, by hardworking archaeologists, paleontologists, lucky explorers and others, coherently explained now better and better over about 150 years.

Many have seen the picture of a beautiful, fluted stone spear point lying between the ribs of a long dead bison in Colorado, a kill about 10,000 thousand years old. It's one of the great examples of paleo-Indian hunting on the Great Plains of America long ago. I commend your attention to the beauty and elegance of that spearpoint. There are a great many others found, some even bigger and more spectacularly worked, but not found among bison bones. You look at them to feel that there's an enormous cunning, the utmost lapidary art, in making that kind of a point from hard chert. People who have learned by slow trial how to do it today say that it takes several hundred carefully calculated blows of the right tool on the right place on the right sample to produce one of those beautiful spearpoints, ideal for hunting mammoth and bison in those long-gone times.

Now, I want to raise a question. It's an easy question, yet a puzzling one. What distinguishes the Old World from New World? What is the real, deep distinction between the two? There is such a distinction, and it just occurred to me rather recently. I wanted to show what arguments lead to it in a very general way. They have nothing whatever to do with Columbus, or for that matter with Leif the Lucky or Eric the Red or even Saint Brendon, or anybody else you can give a name to. No, no, the distinction I see is far deeper and older than that. It arises from the history of our whole species. It affects not just this nation or that, but all human beings one way or another, but it does sharply distinguish the Old World from the New.

We are not the first of the hominid strains. We all know that. Everybody who watches television knows that. We are all of one species now, all human beings on Earth today are of one species, whatever their land, whatever their language, whatever the climate in which they were at home, whatever the pigmentation of their skin, whatever the mix of their blood groups. We know very well that humans are freely interfertile. There's no question about that. We are one people, the only species now on Earth with the full capabilities that we have for good or for bad. I'm not making a judgment here, but stating a fact.

One of the arts we have done for a long time—this species, our species—was that beautiful work of the hand that we see in the admirable flint points. But long before our time, we had forebears. They were in their day also very cunning and very able, but much poorer, much less handy, with much smaller brain cases, yet on Earth long before us. They were creatures different enough to be placed in another species from our kind (even two or three or four other species, but those finer distinctions we can for now overlook). *Homo erectus* is one of the best names for them, and we find their work widely spread. The kind of stone work those beings did was quite wonderful too, the hand axes and the chopper tools. But it was plainly not comparable to the later work, much less refined, with much less variety and little change over time and space. Yet they were the Prometheans, the first of animals to learn the use of fire.

The records of their work go far back, dating certainly more than half a million years old, some ten times older than most of the dates we find for our species of humankind. Their choppers and hand axes are items made with a few tens of less precise blows. It is still very knowing work. You and I cannot do what they could do.

Now I say that if there were a place where there have only been people like this, our own species, our own single interfertile *Homo sapiens*, that place could rightly be called the New World, for it had never held any of our old ancestors. There is such a place, and we're in it. In fact, there are several such places. Let me make the argument, and I think you will agree.

Look at a map of the world that shows Europe, Africa, and Asia, the great land mass. It stretches from Britain diagonally to Java, and again from the Cape of Good Hope diagonally to Beijing and the Yellow River. About a hundred major sites are known where the bones and the cruder, earlier stone work of the older people are found. Not a single such site is established anywhere else in the world outside of the three continents of the landmass: Asia, Europe, and Africa.

On the other hand, in Africa, Asia, and Europe there are hundreds of sites that show the ancient work of modern man, of our own species. I don't mean the work of our contemporaries or of any historical people: these are fossil sites, the work and the remains of our own large-brained kind of long ago. They show the same skilled flint working you see in the American examples. In the Old World, of course, New World people were there too, sometimes in the same sites as the Old, only much later. That Old World was the place where New World humans first arose to replace their more ancient ancestors.

Australia has New World sites only, all of them sites with well-made flints. The people still live there who made the tools and the art, the indigenous peoples of Australia. But not one *H. erectus*, not one Old World site, has ever been found in Australia, though we've found ten or a dozen sites of our sapient kind. In all of North and South America, too, we find many scores of sites of fossil tools and bones, but never a single example of the old kind of people; only the kind of highly developed abilities that we all now share.

It seems to me pretty clear. Whether America is the New World does not depend upon any recent historical event. It does not depend particularly even upon dating the finds. They date themselves, not in so many years but in a very realistic way. Wherever the more skillful, more modern people ventured where their ancestors had never gone, that was the New World for human beings. The New World includes Australia and the Americas. We do not know when the Native Americans first came here. But no early human-like people had ever been before them, only those with the full form, skill and ability of contemporary man, our own species, even if many tens of thousands of years old.

Beyond this, there are only two other wide distributions of modern human beings. The lonely Pacific islands were occupied much later than all of this, within the last 5,000 years or so; Madagascar was reached 2,000 years back; and New Zealand only a thousand years ago. The High Arctic around the shores of the Polar Ocean has known humans a few thousand years; some other small islands off India and off West Africa and in the North

Atlantic are also part of the New World in our sense, that world where modern humans reached rather recently, only by travel outside the wide lands of their ancestral home.

You might ask what happened. From the maps alone it must be that the modern species we represent were the first who were able to voyage beyond land, beyond the shallow straits, to pass overseas to Australia and to the Americas. That's the most likely explanation. They were able to do that very early. For in the old times, the voyages were not gigantic voyages in Polynesian outrigger sailing canoes, a development only a few thousand years old, nor the Viking long ships, nor the caravels of Magellan or Columbus. They were small canoes or other clever craft able to cross up to one hundred miles of open sea, once you were good enough at it to risk going out, and coming back if you got nowhere. Once they came to Timor, at the end of Indonesia, there's only one deep spot left before you go to Australia. The water that occupied the shallow seas was piled up as solid ice on ice caps north and south of the world. The glaciers had come there. During the glacial times, voyaging being easier, the shores were perhaps accessible all the way to America, and the abilities of human beings grew greatly.

It's interesting to ask one question. How could that be? What made the glaciers? We don't know it all, though we have some part of the story. Some of the story has to do with the way climate behaves, its feedback loops, the dependence on carbon dioxide, many such things. But part of the story is shown in the rhythms of the ice coming and going over time. It seems to match in part the astronomical rhythms of the earth's orbit.

The earth (the light moon moves with it) does not move in the pure textbook ellipse of Kepler. It would if there were no other bodies but sun and Earth and no relativity; then it would move in an unchanging ellipse around the Sun. But there are other bodies, notably big Jupiter; by their gravitational pulls they modify the earth's orbit slowly and slightly beyond a simple ellipse. It stays near that form, making a kind of rosette of shifting ellipses.

The experts now know the differences. The orbital shifts affect the climate in some indirect ways, imposing their slow rhythms on the climate pattern over time. When the slowly shifting orientation of the earth's axis, the slowly changing tilt of the earth's axis, and the time of year when Earth comes closest or farthest from the sun are in the right relationship, cold winters and cool summers can be expected for a long period of time, as the orbital parameters slowly change and then repeat. The effects seem present even though the whole chain of climate change is not yet clear. This case is probable, not yet certain.

Many have seen a striking film, which has made a great impact on teachers of science, produced by an astronomical group at Harvard College Observatory who undertook to ask the graduating class at Harvard one day what they thought was the origin of the seasons? Some of the cleverest answers came from good Harvard students who were innocent of much astronomy. These ready "theorists" argued that it had to do with the fact that the earth's orbit is an ellipse, so sometimes we're closer to the sun and sometimes we're farther from the sun; maybe that was responsible for the annual seasons? Of course, it's obviously not so; southern Cape Town far south has its few frosts in July, just when Cambridge is hot. Both summer and winter can't be due to solar distance alone!

The quantitative failure is also strong. Anybody who studied anything about it should have learned that. But if the students didn't learn—and manifestly these hadn't—they at least were making a plausible suggestion. It could have an effect. In the case of the slow ice ages, it's an important part of the glacial climate.

We should not be quick to criticize those who perhaps have not learned something simple, but have learned how to make a remark from which inference can be legitimately drawn, one that might be tested in several ways. Maybe that is better than mere remembering what you were told; it is after all closer to the style of genuine science.

It is from such inferences—many of them wrong, and only a few right—that the grand patterns finally appear.

Example 3: Moon Watchers

Eleanor Duckworth, Professor at the Harvard Graduate School of Education, has for years tried with many people in schools and out of them, the following remarkable exercise. It works at any age. You're not too old to do it; your grandchildren are not too young to do it; what you must have is the spirit to try, and occasional clear skies. Look at the Moon whenever you can, any time. Look by day, look by night. Try to understand how to record what you see. Point at it. Notice where it is. Notice its shape. Notice its position in the sky. Notice when it shows a crescent cup, whether the tilted cup might hold water or spill it out. Try to come to agreement—all the persons in a class—on what is going on. Can we reclaim that tale we know people first made long, long ago? Don't look it all up first in the book. That will spoil the game.

See what you can do by your own direct observation, where you must be able to attach some kind of geometrical account. No coordinates need enter, none of that, just a crude statement. Which way were you looking? Was the moon high or low? What do you mean? Cooperatively with your classmates, who together can easily sample more hours than any one person, report the moon as it appears under many different circumstances. Discuss it, argue; sooner or later, you will build up a broad class consensus on what you know. The consensus will change as people correct their reports. And check. A couple of years of that and you'll begin to understand this feature of the sky!

I doubt that the task is right for examinations or among standards of topics, but equally if everything of this flavor were to be excluded, it would be a very great shame. This shares the essence of scientific research: observation, notation, some effort toward the quantitative, some effort at discussion, collaborative concern, common interest, knowing tests. The best part is that students caught at any level become so engaged by it, they can't forget it. They go beyond.

The very first class with whom Eleanor worked this way—a class of pre-service teachers—still meet after a dozen years, many of them every year or two, to discuss moon behavior and moon geometry. We were once invited to talk to them not long ago; they astonished me because they had gotten so far as to argue about the nature of the terminator. What is a straight line on the surface of a sphere, anyhow? *Is* it a straight line? As you know, this is the beginning of spherical geometry, the beginning of curved space, so deeply built into our understanding of today's physics, both very germane and difficult for most people to grasp at all. If you walk in a straight line, controlling your path by sighting before you and behind you to align the path, you will always walk in a great circle, never in a true east-west line (except at the equator). This wonderful truth was grasped by these people from their own observations and discussions of what it could mean to draw the shadow line on the half moon. I found it a remarkable example, and I bring it forward to show how deep even simple actions probe.

The net of this world is very closely woven. It's not easy to enter any place and be prevented from going to any other place through the nodes of connection that exist. Most of science depends upon the physics of matter, space, time. Physics depends upon the evolution of our own senses and our own understanding. It's clear that a kind of order comes out of this which is approached by taking something as direct, as ubiquitous, as time honored as the geometry of the familiar moon, and trying to work out for oneself what it is and what it could mean. It requires the passage of time; a few days will hardly suffice, a year is fine, when a lunar eclipse is apt to bring new excitement as the year passes. What could it mean? Finally, to the books; they can help best when you are self-prepared.

Coda

I close with a final remark borne on me very strongly today, partly by President Kirwan, and by other people as well. We do ourselves a great disservice if we press the reform of science education, badly needed, solely as a task for our K through 12 teachers. They are very important, because most people go to school in those times. But the universities need to look at themselves. Their science teaching to science majors, to premedical students, to engineering students, to mathematics students, is imperfect, yes, but quite good. Those students expect to go on; they expect to enter into the spirit of science, for they will spend half a lifetime nearby.

But the teaching of most men and women, those who will be lawyers, accountants, brokers, legislators, teachers, business people, even poets, is much poorer. It tries too much to bring them closer to the professional world. The major reform of education in the sciences for those who will remain far from the sciences is a badly needed reform within the universities. There are good signs here and there; if that trickle of reform can become a flood, it may wash away a great many of the problems we fear now. For if the school board members, the taxpayers, the Congress, the advertising directors, the journalists are mostly people who recall a dull, inexplicable, taxing course or two in science, they will have little sympathy.

Will they try to build something of a new structure in the schools for something they disliked, something for which they must, all the same, pay?

Physician, heal thyself; university, heal thyself too! Rather let the students recall something not too wonderful to be true, if it be true, and how it was perceived and tested. Certainly not all that is wonderful can be true. That quite popular view is but dream stuff. A society needs great dreams, but one that lives mainly upon dreams is, I fear, due one day for a truly harsh awakening.

Readings

Neutrinos

1986: Abraham Pais, *Inward Bound*, Oxford University Press (history)

1992: Christine Sutton, *Spaceship Neutrino*, Cambridge University Press (supernova)

Old World and New

1993: G. Burenholt, general editor, *The First Humans*, Harper Collins Publishers, New York, NY

Moon Watchers

1987: Eleanor Duckworth, *"The Having of Wonderful Ideas" & Other Essays*, Teachers College Press, New York, NY

An Attractive Remedy: Matching Scientists with Teachers

Irene D. Hays

We know the story. In too many of today's precollege classrooms, little hands-on, inquiry-based science instruction can be found and much of the content-based science curricula is out of date and irrelevant. Teachers are out of touch with "live" science. In fact, most have little more than a nodding acquaintance with the practice of the very subjects they teach. This is a clear disadvantage for those trying to make science come alive for students.

Few opportunities are available for teachers to get in touch with live science or scientists. Few pathways exist for rapid transfer to the classroom of processes used by men and women to advance science or of discoveries on the frontiers of science. Few mechanisms are available for funneling or infusing new content or teaching strategies into the curricula. And little or no incentive is provided for teachers to reach beyond the classroom.

Furthermore, the culture, demands, and constraints of the teaching profession often isolate teachers from normal adult interactions with other professionals and colleagues. As a rule, teachers have limited opportunities for professional development, collegial sharing, stimulation, and growth. Moreover, the environment in which teachers work often mitigates against quality instruction.

Teachers are beleaguered and beset by demands they cannot meet and unnerved by a system that undermines their best efforts. But many are hardworking and dedicated to student learning and achievement. So many "screw their courage to the sticking place," and continue day after day to meet head on—at great personal expense—the students in their charge. Others appear to have lost their nerve completely; no longer able to face the challenge, they sidestep the demands, and fade away—again at great personal expense—marking time to retirement.

A remedy is needed and one is offered—not a panacea, to be sure, but an attractive remedy.

We propose an intervention strategy to renew the science teacher who is unflagging in dedication and commitment. It is a strategy also to revitalize the science teacher clearly flagging, disillusioned, and out of touch. The strategy is to provide teachers with the opportunity to become full-share partners in the scientific community through scientific work experience in a laboratory setting. Characterized by intensive immersion in the day-to-day world of the scientist, the experience frees teachers from their classroom persona and lets them be scientists engaged in uncovering knowledge and solving problems. By matching teachers with scientists in laboratories for extended research experiences, we couple science education with ongoing research.

We are part of a national effort to demonstrate and test this strategy.

Teacher Research Associates

In 1989, the U.S. Department of Energy (DOE) established the Teacher Research Associates, or TRAC program, an eight-week research participation program that includes all DOE laboratories with established science education centers. The TRAC program provides seventh through twelfth grade science, mathematics, and technology teachers across the nation opportunities to participate as research associates with practicing scientific researchers in ongoing research projects at DOE laboratories.

The program began nationally in 1989, growing from a number of pilot programs begun in the mid-1980s at several DOE laboratories including the Pacific Northwest Laboratory, Lawrence Berkeley Laboratory, and Argonne National Laboratory, among others. As a result, a community of DOE education coordinators and teachers began sharing experiences and promoting the development of a broad national teacher research participation program.

The most influential roles were those of the teachers themselves. Teachers shared their success stories with DOE education leaders in Washington D.C., who, as a result, provided increased support for scientific work experiences at additional DOE laboratories and facilities.

Today teachers are selected for the TRAC program from a national pool of applicants, which included nearly 800 for the summer 1994 program. Additional teachers are selected each year by each of the twenty-eight participating DOE laboratories from their regional teacher applicants. In 1994, approximately 400 teachers selected from the national pool of applicants will participate in this program. Others selected from applicants who live in proximity to the DOE laboratories will also participate. At Pacific Northwest Laboratory where I direct education programs, fifty teachers will spend the summer of 1994 with us.

During the early years of the program, we were content to learn that individual teachers reported amazing transformations as a result of their research experience. They reported transformed views of themselves, their students, and their teaching. And they reported increased effectiveness in the classroom.

Now we are engaged in a project to determine whether that self-reported transformation does indeed bring about change in teachers' behaviors in the classroom. Does it change teachers' abilities to influence their peers? How valuable are programs that provide research participation for teachers? Can we find evidence that such programs enhance teachers' knowledge in science and the research process? What evidence is there that their teaching is strengthened and that student outcomes are enhanced by the teachers' scientific work experience?

Evaluation and Capacity Building

Evaluating the Teacher Research Associates program is one component of a four year project funded by DOE and led by the National Center for Improving Science Education (NCISE). The goal is to determine whether DOE's significant investments in science education have had a significant impact on teacher enhancement and student performance in science, mathematics, and technology.

Teacher research participation is one program type being evaluated at DOE laboratories. Other program types include teacher development, such as in-service training workshops and institutes; student focused programs, such as laboratory internships and apprenticeships, and opportunities for mentoring by scientists; and systemic programs, such as comprehensive partnerships with schools or school districts. The latter are intended to represent those programs conducted by DOE laboratories that are part of statewide systemic initiatives. The ultimate goal of the four year evaluation project is to strengthen the capacity of the laboratories and DOE to evaluate the design, implementation, and impact of their programs on students, teachers, and schools.

Evaluation Templates

To find out what it is that might cause change in the classroom, a prior question had to be asked and answered: What is actually happening in the programs? The first step in knowing, then, was to develop a template to be used as a tool to profile the teacher research participation programs. Staff of the NCISE, in collaboration with DOE and DOE laboratory personnel, developed a template as a tool to evaluate TRAC. The template is to help answer five questions about the TRAC program:

- What is "best practice" for teacher research participation programs?
- To what extent is the program designed to reflect what is most effective?
- To what extent does the program in place reflect best practices?
- To what extent is the program's design actually carried out?
- Where are the gaps? What can be improved? What is beyond our control?

The template that was developed not only characterizes the program but also allows for comparison of the program to best practice. The template helps assess the congruency between best practice, the intended program, and actual program operation. In this way, the template is a formative evaluation tool as well as a tool to evaluate the impact. Knowing the answers to the questions helps identify components of TRAC that could be improved. DOE laboratory personnel were trained by NCISE in the use of the template, and the training provided capacity building for continuous improvement.

Generally, a template for a program is based on what research and practice indicate are components necessary for a program to be effective. However, in the case of teacher research participation programs, only a limited amount of research is available. The templates we developed for that program type, therefore, are based largely on the experience of our program staff in combination with experienced researchers from NCISE.

Thus, this evaluation process for teacher research participation programs is viewed as an opportunity to add to the knowledge base on effective practice as we come to know how effective the components of the program really are. I and my colleagues at other DOE laboratories, in effect, operate sites to test and demonstrate effective practice in this type of program. In 1993, the template developed in collaboration with the DOE laboratories and NCISE was used to profile programs at seventeen DOE laboratories.

Impact Assessment

Does a high quality teacher research participation program, such as TRAC, impact a teacher's students and classroom? The second phase of the evaluation model being implemented by NCISE in collaboration with the DOE laboratories is intended to answer this question. An evaluation design for assessing impact is now being piloted at four DOE laboratories, ours included. A wide array of instruments is being used to assess the accomplishment of the goals of the program.

The first data collection occurred in spring 1993 when the summer 1993 participants were still in their classrooms. Teachers' applications to the program were examined, telephone interviews were conducted, and visits to classrooms took place. Evaluators from NCISE interviewed teachers and students, examined teacher and student work samples, and observed classroom behaviors. Teachers were asked to complete surveys and to document their teaching behaviors in a logbook.

Then during the summer 1993 program, the NCISE evaluators visited the laboratory sites and talked with teachers and with the scientists who served as their mentors. Focus group interviews were conducted and teachers were observed in the laboratories and in their group meetings. Interviews were also conducted with the laboratory program staff who conduct the program.

Additional data were collected at the end of the summer from teachers and mentors. Reports were collected from the teachers on their research and on their strategies for transferring the research to the classroom. In fall 1993 and spring 1994, teachers' classrooms were again visited and data collected by the full array of instruments used before the research participation experience.

Now, recall what we wish to learn. Can an eight-week immersion in scientific and technical research and development change a teacher's beliefs and behaviors, and can these changes impact students? At this time the final visits are being completed, the data are being analyzed, and a report will be written. We wait to learn results.

Our Hypothesis

In the meantime our hypothesis is that teachers who experience scientific research change in important ways. For one thing, they now have options to teaching science entirely from a textbook. For them and their students, science has become something to do, not something to read about or a set of recipes to follow. Because of their research experience, we believe that teachers are better equipped to teach the concepts and principles of science and convey to students the interconnectedness of science, mathematics, and technology. And they are able to simulate in the classroom the process scientists use to uncover knowledge and solve problems.

Through a TRAC research experience, teachers may come to know science as a real adventure, with real content, context, and meaning. They may come to know what drives science and engineering. At the very least, they meet the men and women of science: The veil is lifted on the human side of science—on the fun, humor, beauty, joy, love, and passion of science. Simulating in the classroom the rich content and context of science is something the teachers can do because they have experienced it. As a result, they should be better able to attract highly creative, talented students into science and technology. And they should be better able to help all students understand the scientific enterprise and technology issues and prepare them to make informed decisions regarding science and technology in relation to society, the environment, and the work place.

Speculation

Now here is where I enter a world of tantalizing speculation, based on my experiences with the teachers in the TRAC program and association with colleagues from other DOE national laboratories.

Our sense is that teachers who participate in research no longer feel intensely isolated from the practice of science and technology or cut off from their profession. They have become part of the scientific community, a very important part, and they seem to know it. We know that many, after leaving the program, stay in touch with scientists with whom they associated during their stay at the laboratory, or seek new affiliations with scientists elsewhere. Though much in the school system may remain the same, the teachers are different, and better able to cope.

Furthermore, we speculate that what may occur is a "perspective transformation" by the teacher when deeply held views are usurped and displaced by new experiences intensely lived. By taking the perspective of a scientist for an extended period of time, the teacher becomes a scientist, and remains so when returning to the classroom, albeit in a teacher's role. In the words of one student of a TRAC teacher when asked to name a scientist, "My teacher is a scientist."

How can this speculation be explored? We did so last summer in one way by asking teachers to write about their research experience throughout the eight weeks, using a deep writing heuristic, or tool, to observe and analyze the research experience and environment. We used Pike's Tagmemic, a three- to nine-celled questioning scheme to address the "what," "how," and "so what?" of their experience. In their writing, they recorded their experiences in the laboratory and described their views of scientific research and themselves as scientists.

What we know about the use of writing as a "crafting of the self" led me to imagine that not only would a teacher's perspective transformation be revealed in the writing, but that the very act of writing deeply could influence and accelerate change. Can writing about the research experience deepen the experience itself and compress the length of time needed to experience a perspective transformation? Can writing help mitigate the intense isolation many teachers feel from the practice of the very subjects they teach?

We believe that it can. The approach is deceptively simple but well established through research on writing: People who write about subjects come to understand them better. This I learned through years of teaching students to write. Now after an equal number of years in the world of science and science education, I am asking similar questions. I do not know answers to these questions, but, based on samples of teachers' writing, I am motivated to explore deeper.

A National Remedy?

Among those of us involved in conducting teacher research participation programs at DOE laboratories, there is a real sense that we're on to something. And we're not alone. Approximately eighty-five similar programs are now in existence in the United States. In 1992, over 400 companies, 35 government laboratories, and 100 universities hosted teachers for scientific work experiences. Many are one-site programs sponsored by industries, universities, or partnerships among them. Several are multi-site programs, sponsoring one to two teachers at each site such as Research Corporation's Partners in Science and the Bay Area's Industry Initiatives for Science and Math Education. Over 5,000 teachers have participated in such programs over the past several years. Simple arithmetic reveals an enormous potential impact on students across the country.

Examples abound of teacher change as a result of research participation. We each have our favorites. One of mine is Patrick Ehrman, and I'll close with his story.

When we met Patrick, he was entering his nineteenth year of teaching in Yakima, Washington, the heart of our apple-producing country. His school, Davis High School, is Yakima's inner city school where most of the school district's disadvantaged students attend, including a high percentage of underrepresented ethnic minorities.

At Davis High School, Patrick was a good teacher of science, but his passion was coaching volleyball, and he executed his responsibilities well — he produced winning teams.

Then he entered the TRAC program, in the summer of 1986, almost eight years ago, one of the first teachers to do so. Pat's transformation began almost immediately — from being a "good teacher of science," to one who is now gaining national recognition not only as an outstanding teacher but also for his innovations in science curriculum and as a researcher in his own right. That transformation is well documented.

In the beginning, he aggressively pursued opportunities to work at our laboratory and at Lawrence Berkeley Laboratory to help him produce an effective research curriculum in molecular biology which he now teaches. A guidebook for the curriculum was produced by Pat and his scientist-mentors and has been distributed across the country. Students conduct actual research in his classes, partnering with local industries to help answer their questions.

Pat has earned numerous awards including the Presidential Award for Excellence and, most recently, the NSTA Shell award of $10,000. He cycles the awards he wins back to the classroom to benefit his students. Meanwhile, his own research continues. He is now working with one of the foremost biologists in the world, Leroy Hood, at the University of Washington under Research Corporation's sponsorship.

Patrick has become a full-share partner in the scientific community since his first exposure to scientific research as it is conducted in a scientific research laboratory. He has himself become a researcher. But he has never let go of full-time teaching. His energy goes on and on, like the battery commercial. And his former passion for coaching sports has given way to a passion for coaching science.

Notes

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Scientists and Science Education Reform

Myths, Methods, and Madness

James M. Bower

Over the last several years, the deplorable state of public science education, and the perceived consequences of our nation's economic and intellectual vitality, has attracted not only the attention of educators and politicians, but also an increasing number of professional scientists and engineers. As a consequence, a remarkable number of science professionals are becoming or are already involved in attempts to improve public science education.

In keeping with this trend, for the last ten years, I and several of my colleagues at the California Institute of Technology have been working in a close collaborative partnership with the Pasadena Unified School District in an attempt to introduce and support high quality inquiry-based "hands-on" science teaching for all children at all grade levels within an entire urban school district.

As of the fall of 1993, all 650 K-6 teachers in Pasadena have been trained and are being supported to teach a high quality, inquiry-based science curriculum. Program extensions have also begun to be developed into middle and high school classrooms and to other school districts.

Myths of Science Education Reform

For me as a science educator, one of the principal consequences of the development of this program has been the necessity to reexamine many of the basic assumptions that I, as a scientist, brought to our early efforts in science education reform. As success in Pasadena has resulted in increasing involvement on national science policy committees, it has become increasingly clear that these faulty assumptions are actually shared by many scientists and scientific organizations becoming involved in science education reform. In fact, these assumptions are strong enough that scientists tend to independently invent nearly identical programs of questionable effectiveness.

The following sections describe several standard assumptions evident in the design of many scientist-designed education reform programs that our experience suggests are actually "myths." Each section identifies common programmatic manifestations of a particular myth and then makes general comments on each derived from our experience in Pasadena. While several of the points made are admittedly controversial, this listing is intended to at least expose potential reform advocates to several important program design issues. After all, whatever the final structure of a program, it should not be created in a vacuum.

Myth 1:

The primary reason teachers do not teach science well is a lack of science content knowledge.

Manifestation: Teacher training should focus primarily on increasing the level of science content knowledge to teachers.

Comment: An inordinate focus on content can actually reinforce the inadequacy many teachers already feel with their own science content knowledge. Further, when allowed to discuss the difficulties encountered in teaching science, teachers more often emphasize lack of time, materials, or "classroom management" than lack of science content knowledge. This is especially the case if science is taught as inquiry rather than as a body of knowledge transferred by lecture. It turns out that teachers with adequate materials, enough time, and good classroom and science experiment management skills can provide their students with an excellent science education with whatever level of content knowledge they already have. Of course, as these teachers become involved in real science experiments in their classrooms, they inevitably seek additional science content knowledge. In this case the information they obtain is directly related to their own needs as science teachers, not to lists of "what all teachers (or students) should know" generated by others.

Myth 2:

Supplemental teacher training is necessary because too few teachers, especially in the early grades, have been required to take science classes in college.

Manifestation: Provide refresher courses on basic college science to supply the necessary "background" information to be an effective science teacher.

Comment: Teachers who have taken more college science courses tend to model their teaching on the lecture based approach of most university science professors. As a consequence, teachers with fewer college science courses are often actually more amenable to fundamental change to inquiry teaching methods than are those whose examples for science teaching came from college and university professors.

Myth 3:

The key to scientist involvement with teacher training is to provide complex information in as digestible a form as possible.

Manifestation: It is important to assure that all scientists in the program know how to "talk to teachers."

Comment: Watered down lectures often only serve to reinforce in teachers the sense that they are not really capable of understanding scientific issues. Similarly, obviously avoiding "big words" can have the same (or worse) effect as overusing them. Both reinforce the insecurity that many teachers already feel about science. Of course, if teacher training is based on actually doing science rather than hearing about science done by others, this problem is greatly reduced.

Myth 4:

Training a few highly motivated teachers will produce "trickle down" reform when they return to their schools.

Manifestation: Require teachers to conduct in-service training sessions for their untrained colleagues.

Comment: There is little evidence that individual training courses have much effect outside the classroom of the trained teacher. Teachers that have elected to take these courses are often regarded as "special teachers" by other teachers, isolating them from their colleagues, and reducing their effectiveness as teacher trainers. Further, teachers seldom have the means or time to effectively run in-service programs for their colleagues. If systemic change is the objective, then it must be the specific target not an assumed side benefit.

Myth 5:

Teachers are undermotivated to teach science because they do not understand how exciting it is.

Manifestation: Provide lectures by practicing scientists that emphasize how exciting it is to do science.

Comment: When surveyed, teachers actually report that they already consider science to be one of the most exciting contemporary fields of study. However, attempts to transfer the excitement of science through lectures never give teachers the opportunity to experience the thrill of doing science themselves. Instead, science is presented as the purview of the elite. Even programs that combine "science excitement lectures" with later "hands-on" experiments usually reinforce unproductive attitudes. For example, in most cases, the "hands-on" activities are do-it-yourself "cook-book" demonstrations of the sort professors design for their undergraduates, that are intended to assure that everyone gets the right answer. This type of lab is in sharp contrast to inquiries that give teachers (and our own students) the opportunity for real open ended scientific discovery.

Myth 6:

Increasing "scientific literacy" requires an emphasis on contemporary science.

Manifestation: Invite professional scientists to give lectures emphasizing the relevance of their work to modern societal issues.

Comment: While understanding the political and social implications of modern science is clearly important, a specific focus on this objective often indicates a hidden agenda. For example, a teacher training program in modern biology might be intended to directly counteract the effectiveness of animal rights activists. Such political considerations, when they are primary, often directly undermine the open, inquiry-based process that is supposed to define the scientific process. It also places science training programs at risk of using the same tactics as those they are attempting to counteract.

Myth 7:

If teachers are motivated enough during training, they will find a way to obtain the material necessary to teach science in their classrooms.

Manifestation: Training programs need not be concerned with ongoing teacher material or pedagogical support once teachers return to their classrooms.

Comment: Unfortunately, too many teachers now use their own time and income to acquire materials for their classrooms. However, if a program intends to maintain a lasting commitment from large numbers of teachers, direct and continuing school district support for apparatus and expendable classroom materials must be part of the program from the outset.

Myth 8:

The problem with science education is a lack of good curriculum.

Manifestation: The principal "deliverable" of a training program should be the development of new curriculum materials.

Comment: In many cases good science curriculum already exists. For example, there are excellent materials available for use in elementary school. Further, all evidence suggests that curriculum development is a much more costly and time consuming process than can be incorporated in a standard teacher training program. Effective curriculum development requires long term revision, field testing and evaluation by a highly talented, motivated, and educated development team. A reasonable estimate of the cost of developing a real curriculum twelve week module for elementary school, for example, is $300,000 and three years. Curriculum developed in teacher training programs is often mostly of the demonstration variety that does not support good inquiry teaching. Further, an emphasis on curriculum development tends to underestimate the far more difficult problem of curriculum support and implementation. Many millions of education dollars spent on "grass-root" curriculum development programs have not corrected the perilous state of science education in our schools.

Myth 9:

One reason to develop new curriculum is to introduce modern scientific techniques derived from current laboratory experiments.

Manifestation: Base curriculum development on the experiences teachers have working in science laboratories during the summer.

Comment: Modern experiments and experimental techniques are often not accessible to deep process knowledge or active exploration, instead they often appear to be more magical than scientific. For this reason science curriculum should be evaluated for its value as a base for teaching and learning, not solely for its contemporary content. A well conceived series of inquiry-based experiments on even historical subjects can be exciting. Classroom activities developed from research laboratory experiments are very often actually simple demonstrations of previously presented science facts. Such activities bear little resemblance to real experimental science and seldom support inquiry-based learning.

Myth 10:

The most valuable contribution I can make as a scientist involves conveying my deep understanding of the subject of my specialty.

Manifestation: Have eminent scientists give hour long lectures followed by a question and answer period for teacher interaction.

Comment: For many of the reasons already discussed, the value of scientist content knowledge to teacher training programs is minimal. The content knowledge you have is rarely relevant to the needs of teachers in their classrooms. Asking teachers to change their classrooms to fit a scientist's particular area of expertise is impractical and unfair. It leaves most of the hard work to the teacher. In our experience, the principal reasons inquiry-based, hands-on science is not taught in our schools is more related to a lack of resources and teacher support than a lack of content knowledge on the part of teachers. Further, the issues that most trouble teachers in beginning to change the way they teach are questions of classroom management. Few scientists know much, if anything, about this subject.

What Can I Do as a Scientist?

While the foregoing list of "don'ts" might be daunting, in fact, I believe that scientists should be encouraged to get involved in science education reform. Scientists can play a critical role in the process of reform, even if the role they actually play is somewhat different from the role they imagine they should play. The following partial list is based on our experience with several school districts and the many scientists involved in our programs.

Program Validation: Perhaps surprisingly, in our experience, the largest contribution the scientific community can make to science education reform is directly related to the popular perception of scientists rather than anything directly related to their scientific knowledge. Through involvement in a reform program scientists can certify the validity of a program. For teachers, parents, administrators, students, and even funding agencies, the involvement of real working scientists in a science education program can lend essential political support for a project. While this political clout may be a result of what, in my opinion, is the mistaken public impression that professional scientific knowledge is a critical component of any science education reform effort, it provides scientists a tremendous opportunity not available to many other sectors of society (or the educational community). Of course, this makes it especially important that we use the opportunity wisely.

Teacher support: The involvement of working scientists can have a profound effect on teacher optimism. Changing teaching style and/or adopting new curriculum requires tremendous energy and commitment on the part of the teachers involved. Through supportive participation in the process, scientists can provide crucial emotional support for teachers. By serving as a teacher advocate within the program, the school district, and/or the community, scientists can perform an extremely valuable function.

Resource acquisition: To be a professional scientist in today's world it is necessary to have exemplary grant writing and communication skills. Such skills, or the time to use them, are often lacking in school systems. As the current financial conditions of most public schools make the need for outside funding of reform projects critical, scientists can provide an extremely valuable service as grant writers and administrators. Without outside funding, today's reality in public education virtually assures that innovative programs cannot exist.

Modeling the scientific process: While scientists must be very careful in the use of their content knowledge, real science, whether in the laboratory or the classroom, depends substantially on the application of good scientific process. By scientific process I do not mean the famous four steps in the scientific method that are drilled into the heads of children from grade three. Instead I mean the real scientific skills of investigation, critical thinking, imagination, intuition, playfulness, and thinking on your feet and with your hands. We have found that trained scientists, properly prepared and with attitudes adjusted, can easily apply these skills independent of their particular area of expertise. In fact, in our programs we intentionally assign scientists to teacher training groups outside their area of expertise to reduce the likelihood that fun and exploration is replaced by a quickly offered factual answer. In our experience, when scientists and teachers are mixed together in inquiry teams, where no one has the answer (or better yet, where a "correct" answer does not even exist), the results can be magical and extremely valuable for teachers. In our experience, there is no more effective means to convey the excitement of science than to let teachers and students really do science where doing is dependent on involvement in an open-ended, inquiry-based, student driven exploration of almost any subject.

In Conclusion

All teachers, all children: The majority of programs invented by scientists in the United States today are aimed at a relatively small number of self-selected teachers and/or students. In some cases, this focus is a result of essentially elitist views of who can and cannot do science. Our experience in the elementary school grades of the poor urban Pasadena Unified School District suggests that a large number of scientifically gifted students are lost to science well before they have the opportunity to participate in these special programs. In most cases, however, the inventors of programs directed at highly motivated teachers simply assume that once trained, these teachers will be able to galvanize system-wide reform. Unfortunately, there is no evidence to support this assumption.

For these reasons, I believe that effective reform of precollege science education in our nation depends on supporting the professional development of all teachers in service to all students. To do this, it is necessary to explicitly design programs that involve entire school systems, all teachers, and all students. We are already living with the educational and political consequences of this attitude.

Educate thyself: Perhaps the most important lesson that I have learned through my involvement with science education reform is that I knew remarkably little about the educational process before I began. In fact, after ten years of nearly daily experience, my assumptions and those of my scientific colleagues are still being continually challenged by teachers and children. For this reason, perhaps the most important attribute that a scientist can bring to educational reform efforts is open mindedness, a willingness to learn, and a recognition that whatever the value of our own science education, it is likely to have taught us very little about the process of education itself. I believe that this is fundamentally a scientific attitude.

Those seeking further information on the Caltech PreCollege Science Initiative (CAPSI) should direct inquiries to:

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Are We Serious?
What It Takes for Real Change

Luther S. Williams

I am pleased to join you at this point in the forum, just prior to the challenge to action. With respect to the science education continuum in general (meaning science, engineering, mathematics, and technology education), and the K-12 component specifically, one is either impressed or holds in disdain the many issues, programs, and strategies with the profusion of options for scientist/educator collaborations. The list is almost without limit. To name just a few, consider the topics explored at this meeting:

1. Building Local Partnerships
2. Scientist as Volunteers
3. Science for All
4. Family Science - Involving the Community
5. Undergraduate Teaching for Science Teachers
6. Society's Expectations for Science Education
7. Teaching, Assessment and Content Standards
8. The National Education Reform Movement

It is this listing of random and highly particularistic activities or, if you will, discrete and necessary elements of a holo-problem domain that led me to the question—*Are we serious?* Do we understand the problem to which scientific and technical expertise, substantial and effective pedagogical experience, and the constructive sense of citizenship attending the scientific community is directed? Equally, if not more, important are the dimension and scope of this complex enterprise.

I want to say something about the current policy environment that will affect efforts locally and on the national level. First, what is the significance of the transition from national science policy informed by unitary emphasis on military preparedness to one driven by a global economy and America's economic competitiveness? Is the scientific community committed to the difficult and sustained effort required to ensure that science education is appropriate to equip a competent and effective science and technology workforce as an explicit and sustained national investment? Would such a position be in conflict with other dimensions of a scientist's agenda such as funding for fundamental research, technical infrastructure, and product development; the aggregate being significant elements of the scientific enterprise? If we are serious, then the matter of funding for science research versus funding for science education must be addressed.

It is equally important to understand the system in which scientists will join with educators in local action. It is true, in the context of the often stated national fad, "Science for all Americans" or science education for all students, that the nation's schools are ill-equipped infrastructually, programmatically, educationally, and sociologically to respond to this challenge. One must recall that even high school graduation as a societal expectation for other than the elite did not obtain until the middle of this century. In addition, the matter of democratization of America's public K-12 systems as well as higher education was not engaged, albeit most ineffectively, until nearly 70 percent of this century had been consigned to the past. The remarkably inefficient and unproductive K-12 system has, therefore, incurred a substantial cumulative debt. Urban school systems, enrolling approximately half of all school age children in the United States, best exemplify this educational debt.

There is, perhaps, no clearer manifestation of the problem than the continued disparity between the performance of white middle school and African-American and Latino students at the basic achievement level in mathematics. This is the system, displaying a two-fold differential in basic mathematics performance for student cohorts, in which scientists are seeking to link their efforts with those of educators to implement standards-based science and mathematics instruction. This circumstance is made even more difficult by the fact that very few school systems have the basic infrastructure for K-12 math and science instruction. What roles will scientists and their scientific institutions play in addressing this deficiency via direct or indirect means? I submit that without a bona fide elementary and secondary level system, the implementation of science standards will be exceedingly problematic, if not impossible.

The urgency of adoption and implementation of content, teaching, and assessment standards is crucial to any realistic effort to make substantive improvements in math and science performance. This fundamental issue notwithstanding, I can imagine no greater challenge than the education and training of the instructional workforce to make provisions for standards-based math and science education.

In the in-service arena, the magnitude of the national training efforts and the attendant costs could easily be measured in the several billions. An equivalent challenge resides in the undergraduate level science and math standards-based education of the next cadre of entrants into the math and science instructional workforce. Without this instructional capability, little else will be accomplished. What is the role of scientists in this effort? How will the contributions be made?

Another area of challenge, as well as opportunity, is the use of technology and information infrastructure in science education learning. In this matter, it is important to remember that, the frequent call for the construction of the national information infrastructure or the information superhighway notwithstanding, many American schools could be aptly termed telecommunication ghettos.

In response to the aforementioned, the National Science Foundation (NSF) recently has taken the position that resource acquisition must accommodate the transition from programs to results; a literal and profound change in the basic paradigm as it bears on the strategies that inform and activities that define the NSF education and human resources agenda. This transition is characterized by several developments.

1. The directorate was recently reorganized to better accommodate its agenda, including making provisions for an organized unit assigned to systemic approaches to math, science, engineering, and technology education.

2. Owing to a substantial increase in financial resources, it has been possible to accelerate the pace, from incremental and limited approaches, to more fundamental approaches in the math, science, engineering, and technology education, especially in the K-12 sector.

3. The foundation for systemic approaches, whose vitality defines the growth rate of systemic reform, include the following important programs:

   a. Teacher enhancement;
   b. Instructional materials development;
   c. Informal science education;
   d. The young scholars programs;
   e. Precollege programs focusing on minorities, girls, and students with disabilities;
   f. Math and science teacher preparation via the Collaboratives for Excellence in Teacher Preparation; and
   g. Research on teaching and learning.

4. Another major thrust that facilitates the movement to systemic change is the deliberate linkage of educational efforts to the science and technology workforce preparedness, evidenced by the emerging secondary-postsecondary collaborative in advanced technological education.

Thus, taken in combination, a large fraction of the Foundation's increasing resources for education are targeted on comprehensive and multifaceted program designs of problem solving in statewide public school enterprises, in individual school districts, on problems that exist in many schools in a given district, and on imbalances and deficiencies that permeate a substantial fraction of urban and rural school systems. In fact, systemic approaches are now represented in NSF programming for the undergraduate sector and in its enabling activities (e.g., information and technology networking, dissemination, and educational technologies).

This new and fundamentally different order of resourcefulness and productivity expectations has compelled a shift from inadequate, insufficient, and perhaps even ill-defined objectives, to emphasis on documentable measures of progress toward the achievement of specific goals.

Given the many obstacles to systemic reform, these programs seek to catalyze transformations—fundamental in nature—leading to a new vision and new expectations of the school systems; thereby aligning policies, practices, and outcomes with the requisite accountability. In these conditions, the status quo is not an acceptable option.

The Foundation's initial program, the Statewide Systemic Initiative (SSI) initiated in 1991, is operating in twenty-four states and the Commonwealth of Puerto Rico. The first class (the 1991 awardees) of the SSIs was recently the subject of a comprehensive mid-term review. The outcomes of that review speak to the continuing challenge of replication or innovation transferability; scale-up; sustaining the otherwise unconventional partnerships among schools, business, and industry; the utility of performance measures for the projects; and equity. Under the terms of the cooperative agreement between the SSI awardees and the NSF, provision of technical assistance and the conduct of project monitoring, annual status reports and program evaluation are standard components of the SSI program.

The significance of the SSI Program in a given state notwithstanding, the acknowledged educational deficiencies attending urban and rural school systems were the determining factors leading to the creation of both the Urban Systemic Initiative (USI) and the Rural Systemic Initiative (RSI) Programs.

In the USI program, factors bearing on the design and implementation of the program included the unacceptably large performance gap in math and science between white and racial/ethnic minority students and/or between matriculants of inner city schools and more affluent school districts; the less than exemplary socio-behavioral attributes of urban communities; and the concern that statewide systemic reform could have the unintended consequence of increasing the performance gap between resource-poor students and those of schools characterized by resource-adequacy.

The USI planning activity was initially funded in 1993 and the first class of multi-year implementation awards will be made in this fiscal year (1994) in response to proposals from the eligible cities (i.e., the twenty-five cities with the largest number of students living in poverty and the special initiative designed for the District of Columbia public schools). The required elements of the USI are as follows:

a. a realistic yet challenging statement of vision bearing on all students;

b. a comprehensive assessment of the current status (baseline data);

c. a standards-based math and science instructional program engaging the entire elementary and secondary sequences;

d. the engagement of broad community as participants in the design, implementation, and maintenance of the reform effort;

e. realignment of local school resources to extend the impact and complement the objectives of the USI;

f. an efficient project monitoring and achievement assessment activity.

These required elements represent a program designed to counter the existing, patently unequal, opportunity to learn science and mathematics.

The last program in this trilogy is the Rural Systemic Initiative Program (RSI), for which 1994 will be given to planning activities. The RSI will attempt to fuse capabilities and technologies into systems of distance learning, electronic networks of teachers and students, and enable all schools to gain access to national databases and similar resources. The program will serve school districts in rural communities characterized by inadequate overall economic development and a significant number of students living in poverty.

These systemic reform initiatives will foster multifaceted, programmatic designs of problem solving in specific domains with emphasis on scope and dimensionality; innovation transferability; design-redesign based on R&D in practice; economies of scale and control of discovery costs; and attention to productivity gains.

We, therefore, seek to ensure that the Foundation's programs make substantive contributions to solving problems, rather than sustaining limited programming. Under this new mantra, the possibility of reducing the burden of adversity experienced by many American students and citizens is deemed feasible. To be sure, it is an objective unobtainable without the individual and collective contributions of the scientific community.

Challenge to Action

J. Myron Atkin

It says on the program that my charge is to issue a challenge to action. But, of course, that is superfluous. One can't help but be impressed after two days of listening to you, observing the poster sessions, tuning in on the conversations—with the experience, with the knowledge, with the intelligence, with the commitment to improving science education that's evident at this Forum. The amount of energy displayed here hardly needs a call for action.

Furthermore, this energy comes from many sectors, a relatively new development in American education on the scale that we see it now. It comes from those of us who have professionally been involved from the beginning of our careers in working with young children, but it also comes from industry, people in the local community with backgrounds in science, as well as from those who work in universities. We have a broad array, fortunately, who are willing to focus their attention and devote their energy to trying to improve the science education.

Unlike many periods of the past (and I've been around long enough to have been through several), there is relatively little finger-pointing. "Look," we seem to be saying to ourselves, "It's not your fault, and it's not her fault, and it's not his fault, and it's not their fault, and it's not my fault. Let's put that in the background and work together to try to make conditions better for the children in America's schools." And that is an encouraging climate. Collaboration is the watchword. The poster sessions revealed, and many of the small group discussions confirmed, emphatically, vividly, and inspiringly that people like to work together if they know how they can make contributions to a common cause.

This change in today's setting for the improvement of science education, I think, reflects another shift—not only in science education policy, but in education policy more broadly. We may have passed the time when we felt that education could be improved with a quick fix. In my more optimistic moments, and I'm very optimistic after these two days, I think in the public consciousness and on the policy scene, education may have achieved—may have achieved—what environmental issues have achieved with regard to the attention that they're getting. That is, we've come to realize that we're not going to fix the environment tomorrow, that it takes constant effort, that in the year 2015 or 2020 and 2030, we'll still be worrying about improvement of the environment. We have to run hard to stay in place.

I think there are signs that we're getting to such a stage in education, also. There are no quick fixes, and we'll have a meeting like this in 2025, and we'll be concerning ourselves with some of the same issues. Education demands constant attention. That's a new insight. There were many fads of the last four or five decades—back-to-the-basics, career education, cooperative learning, you name it. We'll solve all the problems. The spotlight usually shone for two or three years, and then public attention went off to something else. One of the broad considerations that people like Luther Williams have made us aware of, people like Mike Smith, people like Bruce Alberts—is that the problems are broad, we have to work on all of them, and it's going to take steady effort. As one of my colleagues says, "If you're engaged in education reform, you've got steady work."

Now I'd like to close with suggesting that, indeed, Sigma Xi not only has a lasting assignment, but, quite possibly, a unique one. Let me remind you that Sigma Xi is a chapter-based organization. It's quintessentially local. More than 500 chapters are scattered across the country. All of those who concern themselves with systemic reform know that, in the end, it's action in the classroom, action in the school, that makes the difference. And how do you reach out? Well, here we have an organization that represents science and, yes, mathematics and, yes, engineering; and it's in many, many communities across the country; and it has members that are committed to trying to make a difference. Let me remind you that the President of Sigma Xi, who enabled this forum to focus on science education, was Neal Lane, who is now the Director of the National Science Foundation. The Annual Forum is the signature act of the President of Sigma Xi. Neal Lane chose to make his signature a forum on science education. That bodes well. I think it also suggests the realization that this organization of outstanding and productive scientists can really help and be constructive. It's different from many other scientific organizations. One of the differences is that more than half the membership—more than half the membership—of Sigma XI are scientists from industry, from national laboratories, who bring a very special perspective, I think, to what we might do to make science more real for the children in today's classes.

We heard, and we heard eloquently, from people like Jim Bower, about the scientists that children in elementary schools are. Well, yes, but when children get to be around eleven or twelve years old, the prevailing question among a large segment of them is, "So what? What difference does this make?" An eight year old, a ten year old, can be a scientist, yes; it comes naturally, as was made vivid to us. But when they get a little older, the question is, "What difference does science make?" And I think here's where people who are engaged in connecting science with the worlds in which we live, scientists in industry and other special laboratories, can be particularly helpful. Sigma Xi is rich in that kind of resource.

The problems are huge, the talents we need are enormous. Much of the talent is in the organization, and, furthermore, we have the determination in the organization to begin to address really important factors that are necessary for the improvement of American schools. Just look around you. Thank you.

Section II

Workshop Summaries

Eight workshops were presented in two sessions at the forum, with fifteen different workshop presenters. Not all summaries are included. The interactive workshop presentations were obviously difficult to capture in a narrative paper, but an effort was made to communicate the essential information presented.

Strategies for Building University Partnerships

Carolyn Thorsen

How do universities develop partnerships with schools, businesses, other universities? What are the mechanisms for getting a partnership going? How do you get administrative support at your institution? How does a partnership sustain itself and bring in resources to support it? Georgia Tech's Center for Education Integrating Science, Mathematics and Computing (CEISMC) has grappled with these and many other questions in pursuing its mission of improving K-12 mathematics and science education.

Conceptualized in 1991 as part of the College of Sciences, establishment of the Center speaks to Georgia Tech's willingness to assume an important role and responsibility in improving science and mathematics education, as well as its willingness to contribute personnel and resources to teachers and students in Georgia's schools. Not only are scientific and mathematical understanding a way of enriching human experience, society's most complex technological issues need the benefit of some level of public understanding. On a practical level, the quality of our future workforce will determine the quality of our lives.

Because Georgia Tech does not have a department or school of education, all programmatic activity is dependent on partnerships: with schools, with businesses and industries, and with other universities. Because of our genuine concern about the need for scientific and technological talent in the next century, all programs focus heavily on encouraging and supporting underrepresented students.

Many CEISMC programs address the needs of science and mathematics teachers; others focus on the enrichment and motivation of young students. Partnering with business, industry, and research scientists, CEISMC provides work experiences for high school and middle school teachers in science and technology-rich environments. In partnership with Boys and Girls Clubs and the City of Atlanta's Camp Best Friends, CEISMC provides environmental and space science camps for inner city students. CEISMC's KIDS Club festivals are hosted by Scitrek, Atlanta's science and technology museum.

CEISMC serves as a center for the Georgia Initiative for Mathematics and Science, the statewide systemic initiative. It is also the Georgia center for SECME, the Southeastern Consortium for Minorities in Engineering. In collaboration with the American Association of University Women, CEISMC has initiated a statewide gender equity effort which includes five universities and six school systems. In partnership with Georgia State University, CEISMC is providing a teacher preparation program for some 200 Georgia Tech students majoring in engineering or the sciences.

Goals for the Workshop

In preparing for the Sigma Xi workshop, CEISMC staff set the following goals:

- To share CEISMC as a university model for partnership with a systemic focus;
- To help participants develop strategies for forming and sustaining successful partnerships;
- To learn from participants, gaining new ideas for CEISMC.

The Workshop participants were divided into four groups and given various roles to play (science faculty, math teacher, middle school principal, industry researcher, etc.) Each group was given a discussion vignette and asked to go beyond merely resolving the challenge presented to develop solutions with long-term potential that would contribute to systemic change.

Discussion Vignettes

1. *Jeff and Susan work for the office of information technology which coordinates the computer infrastructure for a mid-size university located in a rural area. This rural area covers a large geographical region, but is populated with only a few schools and few qualified science teachers. Teachers and students feel isolated.*

Jeff and Susan believe that modern technology can help alleviate this sense of isolation by providing connections with people outside the region. They offer their services to a grateful school system, but then the real work begins. What types of networks should be set up for the schools? Who pays for and maintains the network? Who trains the teachers? Can the installed network be used to improve the quality of science education in the region?

Group Response

Group members assumed the following roles: K-12 teacher, K-12 administrator, college faculty member, university administrator, business person, parent, and K-12 student. The following strategies were developed by the group to address this issue: define the needs of the school system, K-12; assess the effectiveness of the various technologies in meeting those needs; determine the costs associated with the technology, and review the motivators for using the technology.

The group actually began by addressing concerns of the group members themselves. The business representative worried about hiring students who had little exposure to technology. The K-12 administrator felt that her teachers were doing just fine and that the new technology would overburden them. The parent wanted interactive time with his child so that they could learn how to use computers together. The student expressed concern about her parent who can't even operate a VCR. The faculty member admitted that he had only limited exposure to the technology being discussed. The K-12 teacher expressed frustration that industry desires employees with technological skills which are far beyond her own capabilities.

Next the group discussed problems associated with the installation and use of new technology. School hours are such that a working parent could not access the technology. Hardware and software installation and maintenance were discussed. Who pays for these items? Who is responsible for maintenance? Who has time to learn how to use the technology?

Although the group did not get to explore all aspects of the vignette, they began to formulate a vision of how the technology might be used. The schools would remain open after regular school hours so that parents, students, teachers, and administrators might receive training and practice in using the technology. The schools would be connected to the university, the local business and to homes. The local business and the university would share technicians with the school system for hardware and software maintenance.

II. East CEISMC is a neat, well-kept middle school attended by students from a mixed socio-economic neighborhood. A group of concerned teachers meet to review their students' performance on standardized science tests. The students perform above the national average and make reasonably good grades in class. However, the teachers are concerned that their students are unable to relate science to their everyday lives. The eighth grade science teacher approaches her next door neighbor, a research biologist at a local university, for help in making science more relevant to East CEISMC students. What does the biologist do?

Group Response

The group identified two opportunities: presenting inquiry-based science and conducting summer programs for students. Among the constraints were: school policy, time, lack of incentives for faculty, fear of science and negative stereotypes of scientists.

They suggested several issues that a partnership would need to consider before addressing the teachers' concerns. These were:

- Commitment of individuals and institutions;
- Awareness of educational needs and workforce perspective;
- Endorsement of policymakers;
- Education of general public to overcome the "fear" of science and scientists;
- Alliances with non-political groups, such as Sigma Xi;
- Reward participation; begin small—one school, one class;
- Review school and university policies that inhibit fruitful partnerships; and
- Focus on systemic solutions.

III. A group of teachers, engineers, scientists, and mathematicians meet to design a school/classroom collaborative to foster interaction among the teachers, engineers, scientists, and mathematicians on current content, technological applications, and career opportunities. The collaborative wants to foster long term professional relationships for the improvement of science and mathematics education within the community's schools. Initially, a facilitator from outside the community will schedule site visits by faculty from a university 50-100 miles away who are accustomed to making presentations in middle schools. Design the collaborative and a plan for making it self-sustaining.

Group Response

Group members selected roles and a facilitator was selected. The group decided that three questions should be answered: Who will organize? How ambitious should our efforts be? How do we begin?

The group then discussed *goals* and expectations. They agreed on three goals for the collaborative:

- Identifying local applications of science, mathematics, engineering, career option and summer opportunities for students;
- Determining effective ways for volunteers to help the schools; and
- Soliciting administrative support for the efforts of the collaborative.

The group explored *constraints*. These included: demonstration of need by the participating school systems; cost; accountability; bottom line; availability of human resources; availability of physical resources; connection to systemic change; and ability to maintain and institutionalize the change.

The *strategies* proposed by the group were: analyze the external and internal environment; identify roles, responsibilities, and specific assignments for participants; develop consensus building skills; provide training for both teachers and scientists; select developmentally appropriate activities with real world applications; use block scheduling for middle and high school activities; identify funding sources; and develop a public relations plan.

A number of possible activities were then discussed. They included help sessions; shadow programs; parental involvement during PTA meetings; grant writing workshops; release time for business/industry representatives; pre-college courses taught by business/industry representatives; mentor programs; and recruiting volunteers, retirees, and undergraduate students.

Lessons Learned from the Mathematics Standards

Linda Rosen

> "Cheshire Puss," she began . . ."Would you tell me, please, which way I ought to go from here?"
> "That depends a good deal on where you want to get to," said the Cat.
> "I don't much care where—" said Alice.
> "Then it doesn't matter which way you go," said the Cat.
> "—so long as I get somewhere," Alice added as an explanation.
> "Oh, you're sure to do that," said the Cat, "if you only walk long enough."

Current widespread dissatisfaction with the state of U.S. education is coupled, in many people's minds, with the urgent need to get somewhere else and to get there fast. But we don't want to just start walking as the Cheshire Cat suggests. The trick is to first figure out the appropriate direction, identify the people who should accompany us, and specify the signposts we should look for along the way.

Luckily for the science community, a scouting party has been sent ahead. The scouts have learned a great deal in the process, surmounting some obstacles and identifying and labeling others. It is the experience of this scouting party—the mathematics education community—that will be described today.

First, a bit of history. The development of the mathematics standards was motivated in part by two events: (1) the release of *A Nation at Risk*, the 1983 report of the National Committee on Excellence in Education and (2) a 1984 meeting of the Conference Board of the Mathematical Sciences (CBMS) which represents the fifteen major professional societies in mathematics and mathematics education.

Two themes emerged from the CBMS meeting. First, an urgent need to develop descriptive, broad objectives for the mathematics education of *all* students that would be voluntary and respectful of local authority. Second, an equally urgent need to create an action-oriented national steering committee that would help build support for these broad educational goals. The first prompted the

National Council of Teachers of Mathematics (NCTM) to begin work on developing standards; the second prompted the creation of the Mathematical Sciences Education Board (MSEB) at the National Research Council.

More recently, professional societies representing mathematics in higher education followed the lead of NCTM in undertaking the development of guidelines for programs and departments and for the academic preparation of faculty.

What followed in the years since has been a well-orchestrated process to articulate and implement broad goals in mathematics education, kindergarten through graduate school. One sign of this process is a series of publications *(Attachment A)*. Just by its length, the list represents an effort to keep mathematics education reform regularly in the public eye. Closer examination reveals several other important characteristics about the publications: they cover precollege and undergraduate mathematics, and represent the views of different organizations; they are intertwined (NCTM, Mathematical Association of America (MAA), and MSEB all published documents in 1991 dealing with teacher professionalism); they build on one another *(A Call for Change*, and *Heeding the Call for Change)*.

Another sign of the orchestration is the purpose for which the mathematics education community developed standards and guidelines. They sought a banner for what is valued in mathematics education that could serve as a rallying point to facilitate reform. Under this banner, they express their expectations publicly, symbolize their professional values, communicate their goals, and create a compelling vision of state-of-the-art mathematics education.

The mathematics community made the commitment to create standards and demonstrated their commitment by offering their money and time. Paid for by NCTM dues, the standards are truly a product of the mathematics teaching community. Moreover, subjecting draft standards and guidelines to extensive critique within the community helped ensure that the final documents reflected widespread consensus among the professionals, and provided a constituent group to promote their message.

The lessons learned from the experience of the mathematics community can be summarized as follows:

- **Reform is multi-dimensional. Complex systems are unpredictable and require simultaneous attention on many fronts.**

  Many stakeholders must be involved, including teachers, principals, parents, citizens, mathematicians, and administrators. Reform must proceed along several fronts and at several levels:

classrooms, schools, apprenticeships, districts, colleges, and universities. Change must occur in curriculum, instruction, and assessment concurrently, and must be reflected in textbooks, publications, tests, teacher preparation, legal regulations, union rules, meetings, and professional societies.

- **Programs must be constructed anew because behaviors and beliefs resist change.**

  The uniqueness of each site and the inherent resistance to change—from individuals and from institutions—must be considered in the reform process. Prophet-driven programs cannot be sustained. Good ideas should be planted and nurtured, but allowed to grow on their own so that they reflect local circumstances, values, and goals.

- **Implementation emerges from consensus, not from enunciation.**

  Building consensus is a crucial step in developing standards. Input gained from the consensus building helps refine developing standards and highlights areas of contention for reconsideration. The process also increases "buy-in" among professionals; rather than being told how to change, input from concerned individuals is used to shape the final product. Stakeholders truly have a "stake" in the standards.

- **Premature judgments of progress are meaningless. The opportunity to learn from mistakes will be invaluable to the process.**

  The complexity of the system makes it inevitable that change will not be fully synchronized. Curriculum, instruction, and assessment that are not aligned with one another and with the broad goals of reform will cause some missteps. Yet, failure is often a sign of progress, a signal that change is taking place. Bold innovation should be the hallmark of reform, without the fear of failure.

- **A shared vocabulary is needed to further reform. There will be no progress without communication.**

  Much of the initial response to reform may be shallow, rooted neither in a deep understanding of educational change nor in a shared mathematical vision. Stakeholders may talk "past each other" without realizing that they are not communicating. Frequent efforts to explain rhetoric are needed to ensure a common understanding of the goals of change.

Perhaps the greatest lesson of all is that there are always new lessons to learn, since the rhetoric often outdistances the reality of what is known and what can be done. The complexity of the educational system still challenges and occasionally confounds change. An ever-widening audience brings great diversity—sometimes with considerable skepticism—to the discussion. And, the public rightfully demands accountability from reformers who want to change the education of America's children.

Nonetheless, the mathematics community is delighted that science—along with other disciplines—is embarking on the development of standards. Together we will purposefully get "somewhere"—a challenging, vital education for all students who will grow to maturity in the 21st century.

Attachment A: **A Decade of Standards**

1983	*A Nation at Risk*
1984	CBMS Retreat
1985	MSEB established; work begins on the NCTM Standards
1989	*Everybody Counts* (MSEB)
	Curriculum and Evaluation Standards for School Mathematics (NCTM)
	Reshaping Undergraduate Mathematics (MAA)
	Calculus for a New Century (MAA & MSEB)
1990	Governor's Education Summit: National Education Goals
	Reshaping School Mathematics (MSEB)
	On the Shoulders of Giants (MSEB)
	Challenges for College Mathematics (MAA & Association of American Colleges)
1991	*A Call for Change: Recommendations for the Mathematical Preparation of Teachers of Mathematics* (MAA)
	Professional Standards for Teaching Mathematics (NCTM)
	Counting on You (MSEB)
	Moving Beyond Myths: Revitalizing Undergraduate Mathematics (National Research Council)
	Work begins on standards in other disciplines
1992	*Heeding the Call for Change: Challenges for Curriculum Reform* (MAA)
	Guidelines for the Academic Preparation of Mathematics Faculty at Two-Year Colleges (American Mathematical Association of Two-Year Colleges–AMATYC)
	Measuring Up: Prototypes for Mathematics Assessment (MSEB)
1993	*Measuring What Counts: Principles of Mathematics Assessment* (MSEB)
	Guidelines for Programs and Departments in Undergraduate Mathematical Sciences (MAA)
1994	*Guidelines for Mathematics Departments at Two-Year Colleges* (AMATYC)
1995	*Assessment Standards for School Mathematics* (NCTM)
	Standards for Content, Teaching, and Assessment of School Science (NRC)

Scientist Volunteers: Doing Science With Children

Gayle M. Kirwan

The number of scientists who are volunteering to visit school classrooms is growing. Unfortunately, when some scientists visit classrooms, they are so eager to help students learn science that they cram as much information as possible into their presentations. The result is almost always disastrous.

If you are a scientist volunteer, recognize that the amount of time that you spend with a group of students is likely insufficient to effect real change in their understanding of science concepts. What you can do as a scientist volunteer—and do very successfully if your visit is well planned—is provide students with a positive science experience that may cause them to re-evaluate their attitude toward science. One of the best ways to do this is to involve students in a novel hands-on activity that engages and maintains their interest. Here are some suggestions to help you.

Before visiting a school classroom, it is extremely important to plan the visit with the teacher. After all, the teacher is the expert on teaching, and is also most familiar with the content background and abilities of the students in the class. Items to discuss with the teacher in advance include:

1. **Physical Facility** – Find out the physical arrangement of the classroom. Do not assume that there will be running water, electrical outlets, or even large work tables. If you need such things, check to make sure they are available. It may be possible for the teacher to arrange for the class to meet in another room that is better suited to your needs. In some cases you may have to make adjustments to your presentation.

2. **Topic of Presentation and Student Background** – Do not feel constrained to only make science presentations related to your career specialty, especially if you are volunteering in the lower grade levels. Most microbiologists, for example, know enough about basic electric circuits to do a terrific hands-on lesson with fourth graders. It is probably best if your presentation relates to the science topic the class is currently studying. Once you and the teacher have decided on a topic, inquire as to whether there are specific areas related to the topic of your presentation that the

teacher would especially like you to cover. Also find out what the students have already learned about the topic and, in particular, the related science vocabulary terms with which they are familiar.

3. **Activity Ideas** – If you already have some ideas about activities you would like to conduct, bounce them off the teacher. It is important to remember that an activity that seems fascinating to you may not be at all interesting to younger people. The teacher should be able to assess whether an activity will be appealing to and appropriate for the students. This also assures that—horror of horrors—you do not conduct an activity that is a repeat of one the students have just completed!

4. **Materials Needed** – Do not assume that you will necessarily have to bring all materials you need. The teacher may have most of the materials you need. For example, if you are going to do an activity related to magnetism, there is no sense in lugging several sets of heavy bar magnets to school when there may be plenty of perfectly good magnets there already.

5. **Student Names** – For disciplinary and other reasons, it is helpful if you can call on the students by name. Ask the teacher to provide you with a seating chart, or to prepare name tags for the students to wear during your visit.

6. **Grouping** – If you plan to have the students work in small groups on an activity (which is an advisable thing to do), get the teacher to help assign students to the groups. The teacher can specifically inform you of students who do not work well together.

7. **Class Management** – This is an *essential* item to discuss with the teacher prior to your visit. Make it absolutely clear that you expect the teacher to be present in the classroom during your visit and to assist with class management. Otherwise, believe it or not, some teachers will view your presence as an opportunity to leave the classroom to take a break or to attend to other business.

8. **Attention-Getting Devices** – When kids are noisily engaged in an activity, you may find a need to quickly get their attention. Many teachers have a signal with which the students are familiar—blinking the overhead lights, clapping the hands, and so on. Find out how the teacher gets the students' attention. If no set way has been previously established, let the students know how you will alert them to stop whatever they are doing and give you their undivided attention.

When selecting activities for a classroom visit, consider the age and developmental level of the students. If students are very young, it is important to remember that they do not share well. This means that if you plan to work, for example, with magnifying glasses, you better have one for each youngster in the class. Younger students also have extremely short attention spans, are concrete thinkers, have limited math skills, may lack fine motor skills, and cannot remember too many instructions at once. Older students, in the middle grades and beyond, have higher level thinking skills and are better able to handle quantitative data. They have longer attention spans, but they are also more easily bored. While they can also better understand verbal instructions, it may be wise to provide them with written ones because they are not always good listeners.

Select an activity that involves students in the process of science. Make sure that every student can participate in the activity in a meaningful way. Other factors to consider when deciding upon an activity are materials, physical setting, time, and safety. Do you have access to the required materials in sufficient numbers to allow the students to work in groups of no more than three or four? Is the physical arrangement of the classroom appropriate for the activity? Will students be able to complete the activity without rushing, leaving ample time for follow-up discussion and closure? Do you have any doubts about the safety of the activity? If so, it may be best to choose another activity.

Once you have chosen an activity, it is critical to think about the logistics of conducting the activity with students. This is an area of planning that is too often overlooked. Decide, for example, when and how to distribute the materials for the activity.

You might pre-sort materials into bags or other containers in order to quickly distribute them at the appropriate time. You may use student volunteers to pass out materials, employ an assembly line approach, or even have the materials laid out at work stations in advance. Keep in mind that if materials are intrinsically interesting to the students, such as liquid crystals or mealworms, it is best not to distribute them in advance if you first desire the students' attention. Develop a distribution plan based upon the nature of the activity, the kinds of materials involved, the physical arrangement of the room, and the characteristics of the students.

You should also have a plan for collecting materials and cleaning up. Always have the students clean up their work stations before proceeding to another activity. Make sure there are enough well-located trash receptacles and, if needed, plenty of paper towels.

Plan in advance how you will introduce the activity to the class. The best activities are ones that can be introduced with a question, problem, or challenge. Your introduction should engage the students, pique their curiosity, and make them eager to get started with the activity. While students are actually conducting the activity, circulate about the room asking all types of questions. Make sure some of your questions are open-ended. Be sure to allow students ample time to think about and frame their responses. Also, when students ask you a question, instead of answering directly try to respond with another question that helps direct their thinking.

After the activity, allow time for students to discuss what they have discovered or learned. During the discussion, ask students to supply evidence to support their ideas. In other words, remember that "How do you know?" is just as important to ask as "What do you know?" Do not be too hasty in evaluating individual students ideas, but do be sure to provide closure to the activity.

There are several other things you can do to ensure that your visit is a positive experience for both yourself and the students:

- Speak in a conversational tone—don't lecture.
- Use language the students understand.
- Make what you are talking about real to the students by using examples that are familiar to them.
- Encourage students to ask questions or share ideas, but require them to first raise their hands and be recognized.
- If you show a specimen or conduct a demonstration, make sure it is large enough to be visible to the entire class.

Finally, relax and let the students get to know you—not just as a scientist, but as a person.

Science For All: What Will It Take?

Patricia W. DeBerry

There is growing momentum in the United States for science education reform. National science education standards provide a framework for developing a shared vision for excellence in science for all students. We recognize that it will take all of us working together on multiple fronts to make this vision a reality.

"Science for All" implies that we are willing to acknowledge that what we have done in the past has not worked for large segments of our population. National reports, such as *Workforce 2000*, remind us that the ability of the United States to remain competitive in a global economy is directly tied to the educational opportunities and training provided to those groups in our population who have historically been underrepresented and underserved by school and society. It is projected that by the year 2000, two-thirds of all new entrants into the workforce will be women and people of color.

If we are to provide science literacy for all people, then we must teach students in ways that are economic and efficient. We must first begin by recognizing and appreciating the diversity of learners in our classrooms. Traditional approaches to science education must be expanded to include strategies and pedagogic practices that are consistent with improving the achievement level for all students—white, black, red, yellow, and brown.

We can no longer approach science education from a narrow eurocentric point of view. If we are going to provide science for all, then we must recognize and honor the cultural diversity of our students.

No longer can we approach science education from a cultural deficit model. Practices such as tracking and ability grouping need to give way to cooperative learning strategies and heterogeneous grouping. Jeanne Oakes has studied the effect of tracking in mathematics and science and found little or no evidence to support the proposition that tracking improves student achievement. Tracking is a vestige of a segregated society, and a convenience for educators.

How we view knowledge, sources of knowledge, and "ways of knowing" must be inclusive, and we must recognize that there are many ways to obtain truth, and many sources of knowledge. Many of us cannot separate the "dancer from the dance." How students process and receive information is a vital concern for improving science equity.

Many Hispanic and Latino students for whom English is a second language are hindered in their attempt to learn science by the lack of bilingual programs. For these students the most efficient and effective way to process information is in Spanish, their native language. Bilingual education provides the mechanism through which these students can gain access into the world of science, mathematics, and technology.

Providing for the variety of learning styles in our classrooms is indeed challenging. However, if we are to achieve both equity and excellence in science we must teach children in the style that promotes their best learning. Teachers need to be offered continuous professional development about ways to teach to all learning styles. They must be made aware of the relationship between student achievement, cognitive style, and culture.

We must begin to challenge old assumptions and stereotypical beliefs about who does science. Our classrooms and curriculum materials should reflect the diversity of the learners who sit in those classrooms. We can no longer ignore large segments of our student population because of race, class, gender, or learning style. The American Association of University Women's historic report on *How Schools Shortchange Girls* is but one example of the research needed to make all of us aware of the inequities in our classrooms. Shortchanging girls, minorities, and people of color shortchanges America, wasting valuable resources needed if we are to remain a world power.

The inclusion of women, minorities, and people of color is critical to accomplishing our goal of equity in science. We know what the problem is. How do we go about ameliorating the problem? What do we as teachers, researchers, and scientists know about providing educational opportunity to all?

We know that it is important for students to believe in their ability to succeed. A strong self-concept is essential for student success in any area. Developing student self-efficacy is the responsibility of all of us. We are reminded of the African proverb, "It takes a whole village to raise a child." Interestingly enough, the Omaha Indians have a very similar saying which I came across a few weeks ago. It served to remind me that we are more alike than we are different.

We must provide teachers with training in diversity and multiculturalism. No longer can we hold on to false assumptions about who can learn science. The late Ron Edmunds, a forerunner of the effective schools movement, stated that we can successfully educate all children whose education is important to us. What is needed to ensure science for all is our commitment to the education of all children.

Secondly, there is a need for improved curriculum and teacher preparation programs. The importance of teacher education cannot be minimized; however, we must first believe as teachers that all children can learn. Arthur Bandura's work demonstrates that there is a strong relationship between teacher expectations and beliefs, and student achievement. Brophy and Good have done research in this area and point out the importance of teacher expectations on student achievement. If we as teachers, researchers, and scientists believe that all children can learn science, then this assumption will direct our behavior and pedagogic practices, which in turn, affect student achievement and behavior. "I am what you tell me I am," is played out daily in our schools and communities. Students who are left out often view science as a secret, elite society, closed to the poor, minorities, people of color, and females.

We must identify effective teaching practices that can serve as models for the preparation of teachers. John Dewey believed that children learn best by doing. We must insist that schools provide all children with quality hands-on opportunities to explore and learn science. It is not enough to give mere lip service to Howard Gardner's work on multiple forms of intelligence. We need to help teachers use this information to do a better job of teaching.

Children need to experience learning in different modalities and through different processes. We must develop skill in using alternative forms of assessment in our classrooms. What I am advocating is not a lowering of standards. I am advocating that we provide greater access of opportunity to all students, and that we provide this access in ways that are compatible to a variety of learning styles and cultural backgrounds.

An understanding of cross-cultural similarities and differences will enable teachers to more effectively communicate with all students. Cultural misunderstanding between teachers and students results in conflict, distrust, hostility, and school failure. Ogbu maintains that often black students (involuntary minorities) do not see cultural differences as obstacles that need to be overcome, but as symbols of identity to be maintained. At least three of these cultural characteristics are particularly problematic for black children in school settings. According to Boykin, these three characteristics are (1) style or manner of presentation, (2) use of Black English, and (3) cognition, or the processes of knowing and perceiving information.

It is clear that teachers can do much to bridge the barriers to student achievement in science and other areas by becoming more aware of multiculturalism. The diversity in their classroom can be seen as strengths to increase student growth and achievement.

Partnerships between science, education, business, and community must empower both teachers and parents with the resources to challenge the status quo in science education. Discussions and dialogue can serve as a springboard for the creation of successful programs to promote science for all. It is through honest dialogue and reflection that we can identify "best practices" and champion the inclusion of these programs in our schools.

Sigma Xi along with the National Science Foundation, federal, local and state agencies, school districts, academic institutions, private industry, and other professional organizations must work collaboratively to support systemic reform initiatives. Together they can create public awareness and understanding of the positive and vital role science, math, and technology play in today's world. The success of programs such as Operation Physics, Operation Chemistry, GEMS, FAMILY SCIENCE, COMETS, GIST, and EQUALS need to be replicated and disseminated to school districts. Scientists from both the private and public sectors need to provide support for science education through active involvement in the schools as teachers, role models, and career guests. Collectively, they must support the national science standards, increased training of teachers, and the development of better curriculum materials.

Achieving science equity requires involvement beyond our local community or school. Changes in policy making and decision making about who does science must extend to the state and national levels. We must work through the national science standards and organizations such as Sigma Xi to provide the leadership that will ensure an integrative approach to science education and make science for all a reality.

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FAMILY SCIENCE: What Is It?

Bob Whitlow

FAMILY SCIENCE is an informal science education program designed to teach science skills by having children and parents learn and enjoy science together. Aimed at addressing the underrepresentation of women, and ethnic and racial minorities in science-based careers, FAMILY SCIENCE involves parents and children in kindergarten through eighth grade in science activities that demonstrate the role science plays in their daily life and future.

Family involvement is the key to the program's effectiveness. Parents often look for meaningful involvement in their child's education, and may only lack the direction and support to become mentors for their own children. FAMILY SCIENCE helps parents link school studies with daily life experiences, and uses hands-on learning activities to stimulate their child's interest in science. These activities, which use easy-to-find and inexpensive materials from around the home, will complement the school science experiences for targeted students.

Family classes are usually offered in a series of one- to two- hour class meetings for parents and their children after school, evenings, and weekends. The length, location, and scheduling of FAMILY SCIENCE classes is planned to respond to family and community needs. During classes, parents and children work in pairs and small groups to solve problems, work cooperatively, and "talk science." The activities provide experiences for the entire family that build skills, confidence, and interest in science. In addition, guest speakers and career activities illustrate for parents in the workforce the significance of math and science in their own jobs, and for kids, it highlights the diversity of jobs and the relevance of math and science.

Family classes are organized and presented by parents and or teachers who have received training in one of the workshops provided by the FAMILY SCIENCE program.

Goals of FAMILY SCIENCE

I. To provide opportunities for families to have enjoyable science experiences by presenting:
   - non-threatening, hands-on approaches to learning more about scientific processes, concepts, and themes;

- cooperative learning activities that develop problem-solving, questioning, and communication skills;
- strategies for encouraging all students, especially young women and ethnic and racial minority students in science, mathematics and technology-based studies;
- community classes that schedule time for families to participate in group science activities.

II. To relate the learning of science to future studies and work by presenting:

- information about science curriculum, college entrance requirements, jobs and the workforce;
- opportunities to meet and talk with career guests in family classes;
- activities that highlight the relevance of science to daily life, the workforce and across cultures.

III. To involve parents in their child's science education by supporting:

- informal learning activities that supplement their child's formal school experiences;
- parental interest in school science and mathematics programs;
- learning experiences that use inexpensive and readily available materials;
- opportunities for adults and children to be partners in learning.

FAMILY SCIENCE is an outgrowth of the FAMILY MATH program developed by EQUALS at the Lawrence Hall of Science, University of California, Berkeley. A three-year grant from Chevron, U.S.A., Inc. enabled Northwest EQUALS of Portland State University to develop the FAMILY SCIENCE program for national dissemination. Major partners in the project development are the National Urban Coalition of Washington, DC, and the EQUALS program at the Lawrence Hall of Science, University of California, Berkeley.

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Princeton's Science Advisors: A Neural Network

Daniel Rubenstein

Science education in America is changing. Reliance on textbooks is waning as more and more emphasis is placed on doing science. Memorizing facts is giving way to hands-on experimentation.

Yet, despite wholesale changes in the curriculum, science in the classroom remains a caricature of the science practiced by scientists. Too often students perform experiments in a cookbook fashion. When constraints are relaxed, and students are allowed to experiment on their own, their energies are focused on discovery, not the more complex tasks of hypothesis posing and problem solving. In short, the "minds-on" component so important to doing real science is often missing. As scientists and educators, the challenge before us is to meld the two.

Under the leadership of the Princeton Chapter of Sigma Xi, practicing scientists in industry and academia, and school educators ranging from teachers to administrators, are working together to bring about this transformation.

Princeton's Science Advisor Program is in many ways a neural network. It is about thinking, it contains connections that link sensory input with motor output, and it adapts. Connections between scientists and teachers are at its center. These alliances are established and strengthened when teachers identify needs that scientists try to support. These needs might take the form of answers to questions, donations of equipment, expert advice on scientific protocol, insights for reshaping curriculum, or even for educating local Boards of Education. Since no one scientist is omniscient, links among scientists themselves proliferate, and the network expands. Depending upon the success and ease of use, some of these connections are strengthened, while others die away. The adaptiveness of the system is its strength, since it fosters flexibility and discourages bureaucratic rigidity.

The Princeton Program aims to place a Science Advisor in every school—elementary through high school—in eight school districts, both urban and suburban, in New Jersey's Mercer and Hunterdon counties. So far fifty-four advisors have been placed in fifty-one schools. Each scientist visits his or her school regularly, getting to know the teachers and their needs. Each advisor is trained during a summer workshop led by educators from school districts, Princeton University's Teacher Preparation Program and the Princeton Plasma Physics Laboratory's Education Center. And each advisor is supported throughout the year by the "neural network" of electronically linked scientists who are always on call.

As Advisors learn about curricula—how educators actually teach science, and what they would like to do if they had more time, information, and materials—these Advisors begin to draw upon the rich and varied resources of the network. As front line activists, Advisors interpret and communicate the needs of teachers and their students, and then convert advice, information, and services from the network into usable form. In this way Advisors become both catalysts and conduits working with teachers to enrich classroom lessons and laboratory exercises.

Although Advisors may conduct experiments and perform traditional demonstrations, they interact primarily with teachers, not students. If the teaching and learning of science is to be changed radically, quickly and permanently, it will only do so if practicing scientists help reshape the culture of doing science. Advisors can do this best, and with the most leverage, by making teachers more comfortable and practiced in the real workings of science.

For the most part, scientists do not understand the culture of the classroom, and, as a result, they make poor teachers. Moreover, the fact that there are too few scientists and the need for flexibility is great, eliminates the possibility of scientists being there to monitor every need in a timely fashion. Only by transforming the "sciencing" of teachers, will changes in the way students learn and think about science be long lasting. Only then will teachers be able to shape or improve any curriculum or lesson at any time.

In the Princeton Program, Science Advisors visit their schools at least three hours every two weeks. They visit with the support of their supervisors and CEOs, who have generously helped fund the program. Other scientists with less available time serve as resources in the network. A central office staffed by a coordinator serves as the hub for dissemination of useful educational information. The coordinator channels requests from Advisors to appropriate network scientists with special expertise. As projects and units are developed, the office becomes the library of materials and a resource center for equipment.

Since the program is designed to be a true partnership between the schools and local scientists, teachers and their educational concerns are its driving force. Teachers at all levels help train the

Advisors, familiarizing them with the unique culture—both opportunities and constraints—of the classroom. Similarly, it is the teachers who initiate requests and whose enthusiasm sustains the program. Ultimately, the support and encouragement of teachers provide the energy and rationale for making our experiment a lasting success and for truly transforming the "doing of science" in the classroom.

Sandia Scientists Enhancing K-12 Education:

How We've Done It and What We've Learned[1]

Kenneth H. Eckelmeyer

Sandia National Laboratories became seriously involved in the science education reform movement in 1989 in response to a Department of Energy directive:

> "We must expand our involvement in science education to inspire the youth of America to either enter or feel more comfortable in the fields of math, science, and engineering. With our labs and facilities we are uniquely well positioned to provide major assistance in strengthening science and engineering motivation and education, making it "come alive" for the main body of students who too often fear these disciplines or who cannot relate to them" (Admiral James D. Watkins, U.S. Secretary of Energy, September, 1989).

Sandia's initial effort, the School Partnership Project, contributed Sandia technical staff members to several pilot schools in Albuquerque for the purpose of improving student attitudes toward science. Scientists and engineers with experience in coaching, scouting, and other types of youth work were selected for this project. They conducted monthly in-class science demonstrations and hands-on activities with students on topics currently being covered by their teachers. In addition, they provided tutorials for teachers, assistance with science fairs, and tours at Sandia.

The impact of this effort was assessed by giving identical questionnaires to about 700 participating students (in grades one through seven) before and after one semester of School Partnership activities. The results showed the following:

1. Incoming student attitudes toward science are very positive in first and second grades (more than 90 percent favorable), but declined steadily from third to seventh grade (less than 35 percent favorable by seventh grade).

2. Student attitudes improved substantially as a result of one semester's involvement in the School Partnership Project (the percentage of fourth through seventh grade students with gen-

erally favorable attitudes toward science increased from 42 percent to 65 percent).

Based on these encouraging results, a decision was made to greatly expand the Sandia effort. The next step was to involve more schools with the more potent goal of system-wide reform of elementary and middle school science education in Albuquerque and surrounding New Mexico communities. In addition, the focus of this expanded effort shifted from students to teachers for the following reasons:

1. Leverage – each teacher works with many students, resulting in greater impact.

2. Duration of benefits – enhanced teaching skills would continue beyond the period of Sandia's direct intervention.

3. Ease of communication – Sandia scientists and engineers are, for the most part, more adept at communicating with other adults than with children and adolescents.

A high percentage of Albuquerque public elementary and middle schools, as well as rural and Bureau of Indian Affairs schools in the northwest quadrant of New Mexico, indicated interest in being part of this Science Advisors Project. Over 150 Sandia staff members were recruited, and a master science teacher was engaged to help prepare them for their task. These individuals were given pre-service training in the hands-on, inquiry-based approach to science education that we wanted to foster, and to help them understand how to interact effectively with students, teachers, and administrators.

In addition, a Sandia Science Education Resource Center was established to provide access to activity ideas, supplies for various topic areas, and extra Sandia equipment that could be loaned to the schools. Each Science Advisor (or SCIAD, as they came to be known), was then assigned to a school, and authorized to spend up to one day each week at the school.

The SCIADs were directed not to go out to their school with "a suggested program or solution," but rather with the question, "How can we help you?" SCIADs met with teachers, principals, and counselors to learn about the strengths, dreams, and problems of their schools, and to develop plans for how Sandia and their SCIAD might help.

Because initiatives were tailored to the *expressed* needs of each particular school, individual SCIADs adopted different approaches. Many presented in-class activities with students, similar to those done in the School Partnership Project. Others familiarized teachers with hands-on activity ideas, served as liaisons to help teachers find activity kits, or developed their own activities. Some helped organize, repair, and update science supplies and computers at their schools. Others organized science nights for parents, provided science tutorials for teachers, organized and judged science competitions, or served their schools in a host of other ways.

In the following year, additional initiatives were added. The Science Advisor Project expanded to include in-service and summer workshops in hands-on science activities for elementary and middle school teachers. Afterschool projects were begun in which African American, Hispanic, and American Indian middle and high school students engage in exciting science activities with ethnic minority members of the Sandia staff. A high school speakers program was initiated. Efforts were begun to help other communities begin their own Science Advisors Projects, some via telecommunications and distance learning for remote American Indian communities from Maine to Arizona.

Substantial efforts have been made to assess and improve each of these projects. Questionnaires were given to the Sandia project participants and their school "customers." External assessment groups were hired to conduct in-depth interviews and to make recommendations for project modification and improvement.

Several findings stand out regarding the overall impact of the Sandia K-12 Program:

1. Teachers, particularly elementary school teachers, now feel much more comfortable teaching science than they had previously.

2. Teachers are increasingly engaging their students in hands-on inquiry-based science. Loans by our Resource Center have increased substantially each year, topping 10,000 in the 1993-94 school year.

3. Students exposed to positive technical professional role models have developed much more positive attitudes toward science.

4. Following several years of Sandia activities in most Albuquerque elementary and middle schools, Albuquerque third, fifth and eighth graders scored higher in science than any other subject area in the 1993 Iowa Test of Basic Skills.

5. In a broad survey of community attitudes toward Sandia, 70 percent of Albuquerque residents indicated that Sandia was having a positive effect on schooling and education.

What We Learned

Through our experiences of the past five years, we have learned a number of important lessons about science education. First and foremost, we learned that technical professionals can make substantial contributions to K-12 science education, provided they are supported by their employer, are appropriately trained, and have access to high quality educational resources.

Second, we learned that, in order for education programs to be effective, local teachers and principals must have a sense of ownership that comes from having a significant role in establishing the program directions and approaches.

Third, we learned that the characteristics and needs of students and teachers, as well as the degree to which technical professionals can be effective, all vary substantially with grade level in a variety of ways.

Elementary schools (especially third through sixth grades) provide particularly good opportunities for interventions conducted by scientists and engineers. These are the years during which student interest typically declines most precipitously. But programs like those outlined above can make a significant difference.

Elementary students are enthusiastic, respectful, and easy to work with, making it possible for adults without a great deal of training or experience in youth work or education to interact quite effectively with them. In addition, elementary school teachers frequently know very little about science and are in great need of help. They are typically open and eager for any help that proves to be useful.

Perhaps most importantly, only a very basic level of science content knowledge is required at the elementary school level—virtually anyone with a science or engineering background can provide helpful assistance with the *entire range* of topics being covered, i.e., physical science, life science, and earth science. This facilitates *repeat visits* and the establishment of *continuing relationships* between particular scientists, teachers, and students. It would be difficult to overestimate the degree to which effectiveness increases as these relationships develop.

Middle school students and teachers also have great needs, but are much more challenging. Student interest continues to decline, and the onset of adolescence makes working with them more difficult. A significantly higher level of understanding and experience with the youth culture is required. They are self-conscious and very concerned about their standing in their peer group. They begin to "try on" alternative behaviors and positions, and often alternate between fairly mature and outrageously immature behaviors suddenly and frequently. Despite being boisterous and unruly, they have great needs for positive adult role models who. simply like them—the most important question they're asking is, "Am I O.K.?"

Middle school teachers vary widely in their knowledge of science. Some have been certified in elementary education and may have very little science background. Others are certified in secondary education and have substantial science backgrounds. Regardless, they are identified as *science* teachers, implying that they *should be* knowledgeable in science. This makes them significantly more guarded. Unfortunately, those who most need help are often the most defensive.

The level of content and applications knowledge required of the scientist is somewhat greater than in elementary schools, but remains basic enough to enable the same individual to assist with all topics *within* a given area. A physician, nurse, microbiologist, or game and fish worker would be best qualified to assist throughout the life science topics. A geologist, oceanographer, civil or mining engineer, or meteorologist could assist throughout the entire earth science course. Because working with middle school students and teachers involves additional challenges, the establishment of continuing relationships is even more important than at the elementary school level.

High school programs are considerably different, and require different objectives and approaches than elementary and middle school efforts. Student interest tends to be bi-modal. Some students are beginning to develop serious interest in science and need positive role models and mentors to encourage them and help them deepen their level of understanding. Others are turned-off to science and math—it is very difficult to regenerate their interest.

Teacher knowledge of subject matter is usually adequate, but they frequently need motivational examples of how science is applied to interesting real world problems. Perhaps most significantly, a higher level of specialized knowledge and experience is required, making it much more difficult to develop continuing relationships. Within a given course, physics for example, a mechanical engineer might be well qualified to assist in the area of force and acceleration, but a laser physicist would be much better in the area of optics, and an acoustical specialist better in the area of sound.

Finally, we have learned several key principles which scientists and engineers need to know and follow in order to either conduct or promote quality science education activities. These are listed in Figure 1. Space constraints do not permit these to be discussed in detail here, but these points have been fleshed out in a training guide, which can be obtained by contacting the author.

To date, we at Sandia have made significant inroads in introducing a hands-on approach to science in many New Mexico schools, and engaging the technical professional community in the science education process. Building on this, we now hope to work with others towards a national movement of technical professionals enhancing science education in their local communities.

The key organizational units in this movement should be local. Local alliances should serve as focal points to bring together all community stakeholders in the science education process: teachers, principals, technical professionals, museums, businesses, and others. Through these alliances, local needs can be assessed, and goals and methods established for addressing them. The community's technical professionals, an interdisciplinary group of physicists, engineers, medical workers, and others, can then be trained and equipped for their roles in the educational process.

While the key organizational units will be local, national groups also have important roles to play. Professional societies can make their members aware of the needs and opportunities for involvement, publicize the activities being conducted by their members, recruit interested volunteers, connect them with the appropriate local alliances, and provide support for K-12 efforts by their local chapters.

There will also be a strong need for a support structure to provide things that are jointly needed by all of the local alliances, such as: advice on local alliance formation and maturation, information on national reform initiatives, training materials to help technical professionals interact effectively with students and teachers, publicity and recruiting materials, information to help win employer support for employee involvement, and access to educational resources and activity ideas.

We have found that the technical community can make a positive difference in science education in our schools. We have seen it happen in Albuquerque. We now stand ready and eager to help the national community of technical professionals become productively involved in enhancing science education in other communities across the country.

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[1] This work was performed at Sandia National Laboratories, which is operated for the United States Department of Energy under Contract DE-AC04-94AL85000.

Strategies for Quality Science Education Activities

- **Support and collaborate with teachers**
  - Don't be arrogant
  - Do activities that integrate with and enhance curriculum
- **Recognize your need for planning and preparation**
  - Technical knowledge isn't enough—plan to engage students
  - Take advantage of existing materials and resources
- **Employ sound learning principles**
  - Include excitement and fun
  - Involve students in hands-on activities
  - Provide opportunities for discovery experiences
  - Use applications to stimulate interest in principles
- **Do age-appropriate activities**
  - Concrete versus abstract
  - Applications relevant to age group
  - Consistent with student background and vocabulary
- **Engage numerous senses and learning modalities** of hearing, seeing, touching, kinesthetic, rhythm, group interaction, and problem solving.
- **Balance science process and content**
- **Hypothesize and test by experiment**—develop critical thinking skills and ability to reason logically
- **Demonstrate concern for safety and environment**
- **Build relationships**
  - Be excited and fun
  - Demonstrate that you like them
  - Give lots of positive feedback
  - Avoid one-shot visits
- **Solicit feedback from teacher and students**

Figure 1

Successful Collaborations Between Scientists and Schools

Tom Ostwald

I. Motivation and goals: Why do you want to work with schools? How much commitment do you want to make?

There are many ways to support science education in the schools, but what you do will reflect your motivation and your goals. Do you really like working with children, do you feel it's your duty because of the "state of education," or do you just love your field and want to share with others? Is your goal to serve as a role model or create job awareness, to help produce more scientists and engineers or improve general science literacy? These choices may impact your choice of the grade level that you interact with: elementary, middle, or high school. A third variable will be the amount of time you can contribute, or if not time, how much money or "in kind" materials you can donate or loan.

II. Preparation and discussion with teachers

In order to be most effective it is essential to find out the needs of the teacher with whom you plan to work and the best way to support his/her work in the classroom. Meeting in advance to discuss classroom needs and the teacher's is the way to begin a true collaboration. There may be topics in the curriculum at certain times of the year where you fit in best. Likewise, certain times of day are likely to be better than others. Materials that you can obtain may be most crucial.

A sustained relationship with a teacher and a group of students will be the most likely to impact learning and be rewarding for you. It may take several class periods to become part of the life of the class. The teacher and children have much to teach you about schools and teaching, and probably even about science.

III. Ways to interact with precollege education

Four models of interaction with K-12 education are described below, but the range is much wider. Among the successful collaborations between teachers and technical professionals are two of the sites of the California Science Project: the Orange County Science Education Network and the Sacramento Area Science Project.

Like all the California Science Project sites, the Orange County Education Network at the University of California at Irvine began with intensive summer teacher professional development programs. Because of past connections of the faculty who led the program, faculty at every post-secondary institution in the county were brought into a collaboration working with the summer programs. As a consequence, people are now providing workshops for local schools and districts near their institution. In addition, they loan supplies and equipment to schools when possible. Industrial scientists and CEOs serve as members of an advisory council to the UC Irvine's programs. But, gradually, they have begun their own outreach programs to schools, especially supporting scientists' time to work in elementary classrooms.

Starting again from the summer activities, an "Adopt-a-Scientist" program has been developed by the Sacramento Area Science Project, itself a collaboration between California State University at Sacramento and the University of California at Davis. Scientists associated with the program found other faculty who were willing to work in the classroom at least once a month, and arranged meetings between the teachers and the faculty to establish good matches. A few times a year, all the scientists and teachers meet together to reflect on their experiences and needs. In one case, an entomologist went every week to the same primary class for a year. They developed lessons, did field trips, created costumes. The entomologist developed lessons *with* the teacher—they can probably be repeated without her now. The kids loved the arrangement and the scientist found it most satisfying. Now she works with teachers in this Science Project site every summer as well.

A third example is an industry-initiated program in Santa Barbara County called REACTS. Two industrial chemists decided they wanted to work with schools. After visiting some classrooms on their own time, their company has given them paid time to enlarge the program. Initially, they performed demonstrations with exciting chemical reactions, some of which were dangerous or hard to reproduce. This was engaging, but had the hidden message that only "the guy in the white coat" could do chemistry; not the teacher or the kids. They have come to realize that it's better to have the kids do some reactions themselves. Recently, they have expanded by using the classroom presentation as an introduction to an after-school program run by teachers and parents.

Another way to support science education is to make a place for students in your laboratory. This may be the most meaningful way to get interested in science as a student. One summer, I arranged with ten faculty members to let high school juniors spend ten weeks, nine hours a week in their laboratories. I held a once-a-week session for all of the students to discuss experimental methods and some history of science. It was advertised through the regular summer school catalog, the students paid the fees and got credit. There are other similar programs that include high school teachers as well as students.

IV. Other possibilities

The range of possibilities is wider than these examples. Schools need all kinds of materials and equipment as gifts or loans. Afterschool clubs are valuable, and parents can have science activities provided at evening school meetings. Curriculum planners can use expert perspectives, while school boards can be urged to fund their science programs. Visits to industrial science facilities as well as internships are worthwhile. Foreign language instruction in science is critically needed in some areas. Scientists can make themselves a content resource that teachers can use outside of classroom time.

V. Support the teacher in doing science

It is crucial not to forget that science and engineering involve *doing* something. Make experiments, constructions, inventions, explorations possible for the kids! Go in with the understanding that there is much to be learned in the classroom about teaching and learning and children. In addition, your scientific expertise and ability to clarify the basic understandings of science will be challenged. But it is also imperative to remember that the teacher is the person who is in the classroom all day, every day. He/she must be able to carry out an on-going program of quality science, even when you are not there. If you can make that more likely, the collaboration will be especially valuable.

Effecting Change in Elementary School Science Education

Carlo Parravano

The mission of the Merck Institute for Science Education is to improve the quality of science education during the formative years of kindergarten through eighth grade. To accomplish this mission, the Institute has three primary goals:

- Transform the teaching of science to communicate the excitement and relevance of science;
- Reform the education of teachers to instill in tomorrow's teachers an understanding and appreciation of science; and
- Create a consensus on the importance of elementary science education among leaders in education, business, and science.

Merck has made a minimum ten year commitment of funding and resources to the Institute. During its first few years of operation, the Institute will focus its efforts on school districts in New Jersey (in Hunterdon and Union Counties) and Pennsylvania (in Montgomery County) where Merck has its major operations. The Institute will work very closely with the faculty, administration, and community leaders in these districts to enhance science education in the elementary grades of their schools. Once the Institute's goals have been achieved in these initial partner districts, the Institute will replicate its programs in other districts.

The activities of the Merck Institute for Science Education are designed to support effective elementary science teaching and learning at the individual classroom level, and will involve four principal program areas:

I. Professional Development and Mentoring

The Institute supports teachers by sponsoring professional development programs, with an emphasis on hands-on, participatory science activities. It also matches Merck scientists and experienced teachers as mentors to new or student teachers to help them gain confidence in their ability to teach science.

II. Reform of Teacher Education

The Institute works to reform the education and training of teachers to emphasize science in teacher preparation in order to create a new generation of scientifically proficient teachers, particularly in the elementary grades, and encourages teacher preparation programs to stress science teaching strategies that draw students into the learning process.

III. Resource Center

The Institute houses a Resource Center of state-of-the-art materials and resources to help teachers, supervisors, and administrators revitalize and keep current their science teaching. In addition, the Institute provides training and resources to Merck employees who volunteer in schools.

IV. Policy Support for Systemic Change

The Institute advocates for a reform agenda to stress the importance of math and science education, especially in the primary grades. It also participates in statewide and national efforts to achieve systemic reform of public education.

The Merck Institute for Science Education was established in 1992 with a $2 million grant from the Merck Company Foundation. The Institute, a non-profit organization, is based at Merck Research Laboratories in Rahway, New Jersey.

Beauty and the Beast:

Aligning National Curriculum Standards with State (High School) Graduation Requirements

Bill Linder-Scholer

This "Success Stories" workshop presentation focuses on two key aspects of business involvement in state-level efforts to reform K-12 science and mathematics education:

1. A standards-based systemic reform approach; and
2. The need for business involvement in state-level education policy and practice, as a complement to existing partnership activity with local districts and schools.

An overview of SCI/MATH^MN—Minnesota's standards-based, systemic approach to the reform and improvement of the K-12 science and mathematics education delivery system—is offered as an illustration of the challenges of aligning state educational practices with the national curriculum standards, and as a model for business involvement in state educational policy issues that will enable fundamental, across-the-system reform.

Session participants will leave the workshop with concrete suggestions for structuring corporate pre-college science and mathematics initiatives to promote system-based reform.

Part I: A Standards-Based Systemic Approach to Reform

True systemic reform involves fundamental, system-wide changes that affect all the major components of the system. Standards-based systemic reform for K-12 education began with the adoption of National Education Goals (recently signed into law by President Clinton), including Goal #4 relating to mathematics and science education, and will be reinforced by development and dissemination of national curriculum and assessment standards.

Achieving this national leadership model will not be easy. Nor will it be sufficient for achieving systemic reform and the ability to substantially improve student performance across the system, in all states and in all schools. Alignment of state policy and local practice must follow and must be based on local consensus for alignment.

The existing math standards ("Curriculum and Evaluation Standards for School Mathematics," National Council of Teachers of Mathematics, 1989) and the emerging science standards (National

Research Council, summer 1994) are creating a model for national standards and helping guide the debate about the best ways to achieve system-wide improvements and a manageable system, without losing the best of our traditions of local innovation and local control over the how-to's of classroom learning.

The current focus of this evolution is the struggle by states to align their state curriculum frameworks with the national standards and, more importantly, to restructure high school graduation requirements in order to replace the existing "seat time" model of education with a performance-based scheme in which standards of learning and standards of performance make sense.

SCI/MATH^MN (raising Minnesota to the power of science and mathematics) is a relatively new statewide initiative organized by business, education, and government. Specifically, its mission is to be a catalyst for implementation in Minnesota of the standards-based, performance-oriented vision of education articulated in the NCTM and NRC standards.

With respect to the aims of this workshop, SCI/MATH^MN illustrates the major challenges involved in developing a statewide vision for math and science education reform, articulating frameworks aligned with the national standards, building capacity for system-oriented change at the local level, and involving business in systemic reform.

PART II: Business Support for Systemic Reform

In general across the country, business has been an active player in the school reform movement over the decade since publication of "A Nation at Risk" in 1983, which was a call-to-arms for education and business leaders alike.

Initial business responses focused on a variety of get-involved programs to address specific failings of local schools. School partnerships flourished. Follow-on efforts included school-to-work transition programs and the application of management theories (total quality management, etc.) to education administration. School reform experiments were widespread, thanks in large part to the public policy initiatives undertaken by major state and national business leadership associations.

Corporate support for mathematics and science education focused primarily on activities to promote "hands-on" learning, improving student motivation and career awareness, and technology-based classroom instruction.

However, despite considerable reform activity (during the 1980s) by educators and businesses, relatively little progress was made in reforming the larger system or, more importantly, in significantly improving overall student achievement.

Even now, exemplary programs abound, but overall system performance remains at previous levels, and increasingly we are aware of the fading performance of U.S. school children when compared with students in other countries (especially in mathematics and science achievement), not to mention the glaring inequalities among schools and districts even in a single state or region of the U.S.

A critical and strategic review of past business practices reveals the shortcomings of those isolated and strictly-local activities, and points to the need to expand corporate educational outreach to include state-level education policy and practice initiatives.

For businesses, helping the education community get better student learning performance across the system will mean working simultaneously at local, district, and state levels, and most often in concert with other organizations. Designing feasible system-change initiatives will mean changing our own educational practices—to avoid confusing "enhancement" activity with true "reform" and to escape the misconception that successful pilot projects will automatically and inevitably lead to system change.

In Minnesota, business and industry have helped support and lead SCI/MATH^MN, a Governor-endorsed and legislature-funded statewide effort to achieve standards-based systemic reform for K-12 science and math education. Behind the leadership of the Minnesota High Technology Council, a trade association organized exclusively to marshall business support for education in the state, the business community (working closely with its education and public-sector partners) has found realistic and effective opportunities to pursue truly systemic reforms, including education finance reform, graduation standards, teacher preparation and licensure, statewide assessment, and public awareness as well as the more typical professional development activities that naturally flow from curriculum reform movements.

These broad-based policy initiatives complement the existing education outreach programs that our individual businesses continue to conduct. The combination of local activity and state policy initiatives are our best bet for achieving the hitherto elusive goal of improving overall system performance.

For more information about SCI/MATH^MN, contact Ms. Lisa Clemens, SCI/MATH^MN, 643 Capitol Square Building, 550 Cedar Street, St. Paul, MN 55101.

Strategies for Standards-Based Assessment

Elizabeth K. Stage

New Standards is a partnership of eighteen states, six districts, the Learning Research and Development Center, the National Center for Education and the Economy, the University of California Office of the President, the National Council of Teachers of English, and the American Association for the Advancement of Science working together to develop a system of assessment that allows partners to judge students' work against national content standards. Science as Inquiry is prominent in the National Science Education Standards (NSES). The central metaphor for New Standards is the "best version" of the science fair, where the student has investigated a question of interest; was coached by teachers and community scientists, but takes responsibility for the project; interacts with experts who probe for understanding and capacity to elaborate the findings; and is publicly recognized. Like NSES, New Standards is committed to quality science education for all students. The science fair experience will have to be transformed from its extracurricular status to a central place in the curriculum, from participation by a few to all, from a system of ranking to certifying.

In the Sigma Xi workshop, an on-demand mathematics task, "Sports Laces," was done by the participants *(see Figure 1)* and actual student responses were discussed. The long-term plan for New Standards assessment portfolios in mathematics and science *(See Figures 2 and 3)* was outlined.

Engaging students in sustained investigations and exhibitions of their work, somewhat like a science fair, will require the participation of scientists. Names and addresses of interested participants were collected.

To be placed on the New Standards mailing list and find out about opportunities to contribute to a performance-based assessment of science in your local community, please write to:

Ginny Van Horne
Project Manager, New Standards Science
American Association for the Advancement of Science
1333 H Street, NW, Washington, DC 20005
or call (202) 326-6631; FAX (202) 371-9849
email: gvanhorne@connectinc.com.

How Long Should a Shoelace Be?

Suppose you work for a shoelace company. You receive the following assignment from your boss.

Sports Laces

Assignment: We have decided to sell laces for sports shoes. We will sell different lengths for shoes with different numbers of eyelets. We will offer lengths for sport shoes that have 4 eyelets all the way up to 18 eyelets (no odd numbers, of course). No one has ever sold so many different lengths for sports shoes before. You have to figure out what lengths to make and which lengths go with which shoes, based on the number of eyelets.

We collected some data from store customers last week. It is confusing because there haven't been very many lengths available. That means that sometimes the customers have had to use lenghts that are too short or too long. That's not what we want! We want a unique length for each number of eyelets.

Data from Store Customers with Sports Shoes

Customer I.D.	Lace Length (inches)	Eyelets (numbers)	Customer I.D.	Lace Length (inches)	Eyelets (numbers)
A	45	8	G	54	12
B	54	10	H	24	4
C	26	4	I	72	14
D	63	14	J	54	12
E	63	12	K	72	16
F	36	8	L	72	18

Write your decisions about lace length so the advertising people making the sign can understand it. They want a table, so customers can look up the number of eyelets and find out the length of lace. They also want a rule, so customers who don't like tables can use the rule to figure out the lengths. Don't worry about making it pretty, they will do that, just make sure the mathematics is right. You better explain how your decisions make sense, so the advertising people will understand.

Thanks,

Your boss,
Angela

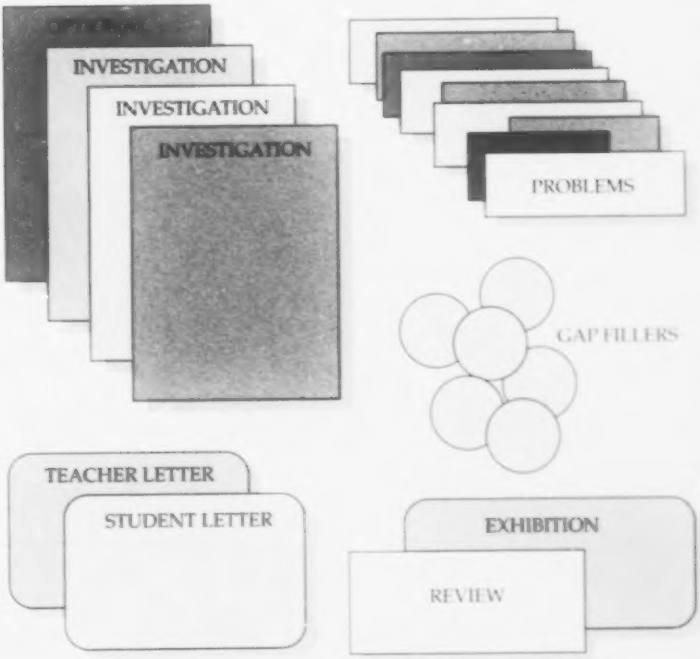
Figure 1a

Write a response to your boss Angela's assignment:

- A table that shows for each number of eyelets (even numbers only) how long you have decided the laces should be.
- A rule that a customer can use to figure out the length based on the number of eyelets. Don't forget the bow. If you can, express your rule as a formula.
- An explanation of your decisions (tell why they make sense).

Figure 1b

New Standards Mathematics Portfolio



Investigations: Showing in-depth, extended work; a project performed over a period of weeks using mathematics to research or design something practical, or investigating mathematical issues, or mathematically-powered interdisciplinary work. Combines group and individual work, and various methods of communicating results.

Problems: Showing problem solving, communication, reasoning, and a range of mathematical techniques and ideas at work.

Gap Fillers: Showing the framework for balance has been covered; selections included so the student can fill major gaps in the curriculum not addressed above.

Student Letter: The student's reflections on his or her work.

Teacher Letter: The teacher's comments on the student's work.

Review: Verifying authorship and understanding of mathematical content, ability to explain and elaborate results, and communicate thinking to others. Applies to the portfolio as a whole, with special emphasis on investigations.

Exhibition: Making standards public to students, teachers, parents, and the community.

Figure 2

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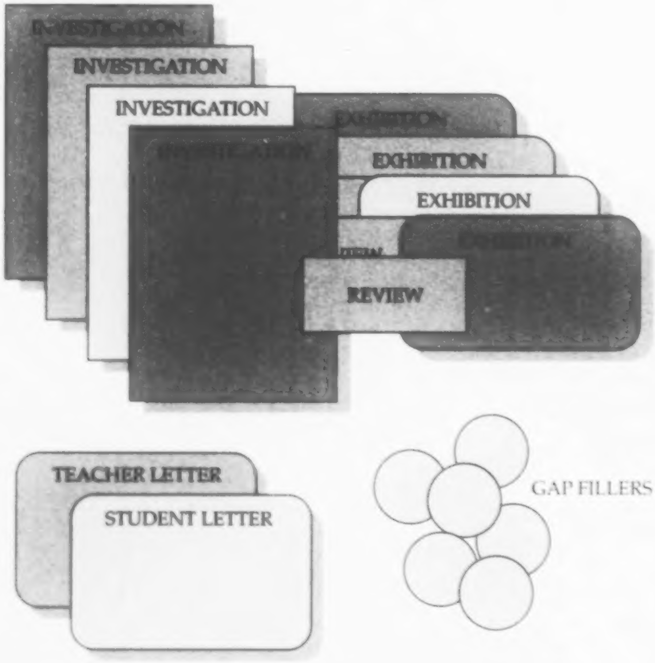
New Standards Science Portfolio


INVESTIGATION
INVESTIGATION
INVESTIGATION
INVESTIGATION
EXHIBITION
EXHIBITION
EXHIBITION
EXHIBITION
REVIEW
TEACHER LETTER
STUDENT LETTER
GAP FILLERS

Investigations: Showing a range of modes of inquiry – experimental, field work, design, and analysis of others' data; group and individual work; various methods of communicating results; life, physical, and earth/space sciences; and other aspects of the science standards.

Review: Verifying authorship and understanding of the science content, ability to explain and elaborate on the results, and to communicate findings to others.

Exhibition: Making standards public to students, teachers, parents, and the community.

Gap Fillers: Showing that the framework for balance has been covered, only for important aspects of the content that are not addressed in the investigations.

Student Letter: The student's reflections on his or her work.

Teacher Letter: The teacher's comments on the student's work.

Figure 3

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Speakers' Vitae

Bruce M. Alberts, president of the National Academy of Sciences (NAS), is noted for his study of the protein complexes involved in chromosome replication. His efforts in science education include such projects as City Science, a program in San Francisco elementary schools. He served on the advisory board of the National Science Resources Center, a joint NAS-Smithsonian Institution project involving teachers, scientists, and school systems, and on the NAS National Committee on Science Education Standards and Assessment.

J. Myron (Mike) Atkin, who has taught elementary school science and written children's science textbooks, is a professor and former dean of education at Stanford University. He has served as chair of the AAAS Education Section and vice-chair of the National Science Foundation (NSF) Advisory Committee for Science and Engineering Education. Dr. Atkin is a member of the NAS National Committee on Science Education Standards and Assessment. He chairs Sigma Xi's committee on Science, Mathematics, and Engineering Education. His current projects include evaluation of science museum programs for adolescents and minorities.

James M. Bower, a computational neurobiologist at CalTech, uses a combination of experimental and computer modeling techniques in an effort to "reverse engineer" the mammalian brain. A founder of the new *Journal of Computational Neuroscience,* he has been involved for the last nine years in Project SEED, which has trained more than 650 elementary school teachers in the Pasadena Unified School District to teach an inquiry-based science curriculum. This program is increasingly regarded as a national model for involving scientists in education reform.

Alphonse Buccino is dean of the University of Georgia's College of Education, ranked among the nation's best research-oriented schools of education. A former NSF executive with more than 30 years of experience in science and math education, Dr. Buccino has served as science advisor to the President and to the White House Office of Science and Technology Policy.

Gerard F. Consuegra is curriculum supervisor for Montgomery County (Maryland) public schools and directs the development and implementation of academic and aesthetics programs from preschool through high school. Serving over 113,000 students, with a wide variety of ethnic and socioeconomic groups, the Montgomery

County system has one of the best student performance records in the country. Its innovative projects in science and mathematics have received NSF recognition and funding. Consuegra has been a consultant to the NSF, *Newton's Apple*, and *Science Weekly*.

Patricia DeBerry is the EQUALS coordinator for the Project on the Study of Gender and Education at Kent State University. A former principal and middle and high school math and science teacher, she is a member of the Ohio and National Council of Teachers of Mathematics, the East Region Project Discovery Planning Committee, the National Alliance of Black School Educators, and the East Regional Teacher Training Center Planning Committee.

Kenneth H. Eckelmeyer is with the Educational Outreach Department at Sandia National Laboratories in Albuquerque, NM. He is the developer and manager of the School Partnership and other local and national K-12 science education projects at Sandia. His research and educational interests include uranium alloy metallurgy, motivational teaching of scientific principles, and organization of K-12 science education enhancement programs. He has written numerous articles on K-12 science education.

Irene D. Hays directs the Science Education Center at Battelle Pacific Northwest Laboratories in Richland, Washington. The Center's programs include teacher research participation, curriculum and teacher development, student incentives and opportunities, and partnerships with elementary, secondary schools, and community colleges, with sponsorship by the Dept. of Energy, the NSF, and Battelle. Ms. Hays serves on the board of the Washington Science Teachers Association, is vice chair of the board of Washington MESA, and is also on the board of the Northwest Consortium for Mathematics and Science Teaching (CMAST). She has 25 years of teaching experience in middle and high school, as well as in university and workplace education programs.

Gayle M. Kirwan is the special projects coordinator in the Education Division of the American Institute of Physics (AIP) and oversees the activities of Operation Physics, a national science teacher enhancement project funded by the NSF. She is associate editor of *WonderScience*, a joint publication of the American Chemical Society and AIP for students in grades 4-6. Kirwan was selected 1983 Outstanding Science Teacher of the Year by the National Science Teachers Association and *Discover* magazine, and received a 1983 Presidential Award for Excellence in Science and Mathematics Teaching. She has conducted many workshops for scientists and teachers.

William English Kirwan, president of the University of Maryland at College Park, is known for such initiatives as increasing and retaining outstanding faculty and exceeding the desegregation goals for the enrollment of black undergraduates. A former editor of the *Proceedings of the American Mathematical Society*, he chaired the Mathematical Sciences in the Year 2000 Committee, a task force appointed by the National Research Council (NRC) to improve mathematics education at the nation's universities during the next decade. He is a member of the NRC's Committee on Science Literacy.

Bill Linder-Scholer is director of community affairs for Cray Research, Inc. and executive director of the Cray Research Foundation. He manages programs for corporate and foundation grantmaking, employee volunteerism, and state government and industry relations. He also is education affairs deputy at Cray Research, serves on the NRC's National Committee on Science Education Standards and Assessment and is on the board of the Council for Aid to Education's MATHCOUNTS Foundation. Dr. Linder-Scholer is a founding member of Sci/Math^MN, an industry/education partnership aimed at standards-based systemic reform of K-12 math and science education.

Penny Moore has been developing programs for the last ten years to improve science education for all students at all levels of education. As the physics teacher in a California high school, her honors classes have grown from 12 percent to 60 percent of the school population. She began the nationwide, middle school Science for Science Teachers Program. Her work is supported by the NSF and Intel Corporation, among others. She has served on the National Physics Task Force for the National Science Teachers Association and is a member of the NAS Committee for Undergraduate Science Education.

Philip Morrison is Institute Professor emeritus of physics at MIT. During World War II, he served with the Manhattan Project, taking part in the test of the first atomic bomb. Since then, he has written and spoken widely against nuclear war and the arms race. In 1959, he and Guiseppe Cocconi first recognized the potential of microwaves in the search for interstellar communications. To promote a wider public understanding of science, he has gone into classrooms at all levels, written textbooks and monthly book reviews on science and technology for *Scientific American* and participated in film and television projects. Dr. Morrison is a member of the National Academy of Sciences. He is the 1994 recipient of Sigma Xi's John P. McGovern Science and Society Award.

Thomas Ostwald is interim co-executive director of the California Science Project, a $2 million, state-wide professional development program in science for K-14 teachers. He is director of the South Coast Science Project at the University of California at Santa Barbara Discovery Center.

Carlo Parravano is director of the Merck Institute for Science Education, based at Merck Research Laboratories in Rahway, NJ, established in 1992 to provide focus and professional direction to Merck's pre-college education initiatives. Before joining Merck, he was professor of chemistry and chair of the Division of Natural Sciences at the State University of New York, where he also directed the Center for Mathematics and Science Education of the SUNY Purchase Westchester School Partnership. He is a recipient of the SUNY Chancellor's Award for Excellence in Teaching. The Center for Mathematics and Science Education, which he founded in 1985, has sponsored nearly 50 institutes and trained more than 2,000 teachers.

Linda Peller Rosen is associate executive director and director of policy studies at the Mathematical Science Education Board (MSEB), where she works on issues in mathematics education, primarily in the areas of curriculum, assessment and teacher professionalism. Her current efforts include work on a research knowledge base to support the fundamental restructuring of mathematics education in the U.S. She has contributed to many well-known MSEB publications, including: *Everybody Counts: A Report to the Nation on the Future of Mathematics Education* and *Measuring What Counts: A Conceptual Guide for Mathematics Assessment*. Prior to joining MSEB, Dr. Rosen taught mathematics at the high school, community college, and university levels.

Daniel Rubenstein chairs Princeton University's Department of Ecology and Evolutionary Biology. His research addresses how environmental variation and individual differences change the adaptive behavior, social structure and dynamics of populations, including the effects of global warming on the social behavior and biology of horses and other species. He is a recipient of a Presidential Young Investigator Award and serves on the advisory board of the Princeton Teacher Preparation Program and Council of Science and Technology. As vice-president of the Princeton Sigma Xi Chapter, he helped launch a science advisor network linking local school teachers with practicing scientists and engineers.

Marshall S. Smith is Undersecretary of the U.S. Department of Education. He is a former dean of the School of Education at Stanford University and director of the Wisconsin Center for Education

Research. He has held several policy positions in the federal government, including chief of staff to the Secretary of Education. He served as an advisor to the National Education Goals Panel and was a member of the National Council of Education Standards and Testing. Dr. Smith has written on a variety of policy issues including desegregation, early childhood programs, effective schools, and the effect of federal policies on state and local practice. His current interests focus on the education of children at risk of school failure, state school reform, and national trends in curriculum.

Elizabeth K. Stage is co-director of the Science of the New Standards Project, a partnership of nineteen states and six large school districts with the Learning Research and Development Center and the National Center on Education and the Economy. New Standards is developing a performance-based assessment system linking students' work with national content standards. She served as director of critique and consensus for the National Science Education Standards Project. A former middle school mathematics and science teacher, she has spent most of her professional career at the University of California, working for ten years at the Lawrence Hall of Science, conducting research and evaluation for EQUALS and Family Math, and developing materials and programs for students and teachers. She began the California Science Project, a statewide professional development program with twelve permanent campus sites, and chaired California's Curriculum Commission.

Carolyn Chesnutt Thorsen is the Director of Precollege Programs for Georgia Tech's Center for Education Integrating Science, Mathematics and Computing (CEISMC). The Center sponsors programs such as GIFT, The Georgia Industrial Fellowships for Teachers, a summer experience linking math and science teachers across Georgia to mentors in Business, industry, and universities; and serves as headquarters for the Georgia's statewide systemic initiative (GIMS). Ms. Thorsen was the founding Director of SECME, The Southeastern Consortium for Minorities in Engineering–one of the first industry/university/school partnerships organized in the state of Georgia. Ms. Thorsen received her M.S. from the School of Industrial and Systems Engineering at the Georgia Institute of Technology, and a masters in education from the University of South Carolina. Named the 1986 Reginald H. Jones Distinguished Service Award recipient by the National Action Council for Minorities in Engineering, Ms. Thorsen was a charter member and past chair of the National Association of Precollege Directors. She chairs the education equity committee of the American Association of University Women and is a member of the Society of Women Engineers.

Jan Tuomi is director of outreach for the National Science Resources Center in Washington, D.C., a K-12 science education improvement program founded by the NAS and the Smithsonian Institution. Ms. Tuomi's involvement in education includes 24 years as an elementary teacher and leader of professional development activities for teachers. Optimizing the involvement of scientists in improving science education is her special interest. She has taught in various communities in California, Colorado, New Mexico, Mexico, and most recently, in San Francisco.

Bob Whitlow is the acting co-director of the EQUALS program at the Lawrence Hall of Science, University of California at Berkeley. He creates and presents in-service workshops for professionals and parents in math and science, with a focus on issues of equity and inclusion of underrepresented groups. For 17 years he served as the teacher/director of the nationally acclaimed Charquin Alternative, a public school program in the San Francisco area dedicated to active family involvement and innovative curriculum and management strategies. Whitlow has served as a member of the Focus Group for Students with Disabilities for the NRC's National Committee on Science Education Standards and Assessment. He was named to the Honor Roll of Teachers by the Association of Science and Technology Centers.

Luther S. Williams is the assistant director of the Education and Human Resources Directorate at the National Science Foundation. Former senior science advisor in the Office of the Director at the NSF, he has served on the faculties of Purdue University, MIT, Washington University, and the University of Colorado. In 1987, he joined the National Institutes of Health as special assistant to the director, then deputy director. He has been elected three times to Outstanding Black Americans and has been named among the Outstanding Educators in America.

Appendix A

Breakout Groups' Conclusions and Recommendations

The Forum breakout groups allowed the participants the opportunity to discuss specific topics more fully. Each group met for two hours on the second day of the forum, and were charged with developing no more than three conclusions and three recommendations. The following were developed by the participants and do not necessarily represent the views of the facilitators, Sigma Xi, or the sponsoring organizations.

Building A National Network

Facilitators: Ken Eckelmeyer, Sandia Labs
Lauren Williams, Triangle Coalition

Conclusions

1. An integrated technical community approach to participation in science education reform is needed. More collaboration is needed among professional societies, technical businesses, and science educators to develop a joint strategic plan, promote local implementation, evaluate the effectiveness of various approaches, and disseminate effective models.
2. There is a need to organize and communicate information and provide resources about the science education reform movement, participating organization[illegible]ntacts, model programs, ideas for employer support, and funding sources through a user-friendly dissemination process. This information should be easily accessed by scientists, engineers, and teachers throughout the country.
3. There is a need to teach scientists, teachers, and administrators ways to work together effectively and maximize their impact on science education reform. Access to high quality science materials and information regarding options for involvement are needed as well.

Recommendations

1. Develop an interdisciplinary group that integrates scientists and educators from professional societies, business, and schools to:
   - develop a strategy to integrate the efforts of technical and educational communities;
   - develop tactics for implementing this strategy in communities across the nation;
   - plan and provide the infrastructure needed for this effort;
   - establish a system of assessment to evaluate models and propagate those which are most successful.
2. Promote and facilitate local or regional alliances for science education reform to recruit, train, and engage local technical professionals, educators, and community leaders to work together in their communities.
3. Develop a user-friendly communication system and networking capability for sharing and disseminating information between scientific and educational communities.

Society's Expectations from Science

Facilitator: Kumar Patel, University of California at Los Angeles

Conclusions

1. Society expects students who complete K-12 education to be adequately prepared for higher education, for the workplace, for their own economic wellbeing, and for lifelong learning since many workers change jobs during their careers. Society expects the educational system to produce individuals who will participate in a competitive national economy.
2. High school graduates should have gained the ability to solve problems and make informed decisions personally, professionally, and as good citizens participating in the democratic process.
3. High school graduates should have developed an appreciation for the aesthetics and importance of science in society.

Recommendations

1. Promote interactive learning among students, teachers, and the natural world. This process will depend upon appropriate school scheduling and small class sizes.
2. Involve *all* interested constituencies in science education reform, including parents, teachers, business leaders, and others.
3. Develop and provide appropriate resources (e.g. texts, science materials, local curricula, teacher training, and assessment tools) consistent with national standards.

Improving Undergraduate Teaching for Science Teachers

Facilitators: Bob Watson, National Science Foundation
Carolyn Thorsen, Georgia Institute of Technology

Conclusions

1. There is a need to integrate science content with appropriate pedagogy across fields.
2. There is a need to coordinate efforts for science education reform between the education and science community.
3. There is a need for teacher certification, assessment tools, and national standards.

Recommendations

1. Colleges and universities should:
    - develop entry-level, interdisciplinary science courses that are inquiry-based and hands-on. It may be team taught, if appropriate, and should address science and society issues. Administrators should provide significant support for this effort.
    - encourage team teaching courses in science and pedagogy (science department with education department or K-12 teachers); appropriate approaches may vary with local situations and education levels.
    - provide funding incentives for innovative ideas that foster education and science department collaborations: e.g. fellowships, grants, release time, or sabbaticals.
2. Delegates attending this Sigma Xi Forum should return to their home institutions (colleges and universities) and initiate dialogue among faculty in the sciences and faculty in education with the aim of identifying problems and formulating an "Action Plan" for improved pre-service teacher preparation.

    Sigma Xi should convene a Task Force composed of scientists and education faculty to:
    - collect research on existing models of successful coordination between science and education communities.
    - redefine standards for science pedagogy from kindergarten through undergraduate that parallel the standards for science content.
    - suggest strategies to establish reward systems and recognition

within the colleges and universities for quality science teacher education.

3. To encourage consistency in teaching to national standards, the Sigma Xi Task Force should identify five model teacher-training programs to:
   - study organization and pedagogical approach;
   - evaluate both qualitatively and quantitatively;
   - disseminate results;
   - advocate for change and assessment of change with the long term goal of all fifty states extending reciprocity in certification and developing a close match with national standards.

Model programs should include collaboration between science and education departments; science courses focused on needs of teachers; and goals connected with national standards.

A minimum base (e.g. two semesters or two courses that integrates science content and pedagogy) should be required for elementary teachers.

A national basis for teacher preparation standards should be established that states would have to embrace to obtain federal support for local programs.

Assessment techniques should be developed that reflect standards-based teacher preparation programs. Older paradigms may not be adequate or appropriate.

Science for All

Facilitator: Patricia DeBerry, EQUALS Program, Kent State University

Conclusions

1. There is a need for basic scientific literacy for all people.
2. If science is for all, we must recognize and appreciate different kinds of cultural knowledge.
3. Our assumptions and beliefs about different groups affect our behavior.

Recommendations

1. Empower people by challenging biased practices and speaking out.
2. Develop a sense of community.
3. Pedagogy strategies should be built around knowledge of different cultures (e.g. gender, race, ethnic).

Family Science – Involving the Community

Facilitators: Margaret Cozzens, National Science Foundation
Bob Whitlow, EQUALS Program, Lawrence Hall of Science

The discussion of this group was based on the principle that science education is a community responsibility. Schools and communities need to work together.

Conclusions

1. There is a need to bring the parents and public *into* local schools, museums, zoos, and other places where science education occurs, who will then carry enthusiasm for science education out to others in the community.
2. Once the community expresses a willingness to become involved, there is a need to provide an engaging learning experience.
3. Once engaged, there is a need to sustain the interest, build collaborations among interested groups, and use this interest to inform decision making.

Recommendations

1. Get the community interested by letting the students "advertise" (through videos, pictures, school visits, or media attention) the excitement of school science activities. The community should be encouraged to become interactive partners with local schools and school systems.
2. Enhance community involvement through projects and activities that have the following qualities:
   - Intrinsically interesting to all (children, parents, business, media, and others);
   - Simple and everyday, so that everyone can relate to the concept and process;
   - Duration should be appropriate to participants' attention span;
   - Provide follow-up for home activities;
   - Provide positive reinforcement (food, certificates, badges, awards, or media recognition);
   - Use parents' ideas and skills in developing projects.
3. Sustain interest and use to influence policy making at the community, regional, state and national level. Science education for

all children requires involvement beyond the local educational community. The formal educational community and the public at large should coordinate educational efforts and should maintain appropriate educational resource databases. A centralized body with representatives from these community-based organizations should coordinate efforts to maximize impact in science education reform.

Federal and private research organizations, universities, and informal science education institutions should provide incentives to their researchers and educators to become involved in K-12 education.

Critique of Teaching and Professional Development Standards

Facilitator: Karen Worth, Educational Development Center

The last three breakout groups were structured as critiques of the NRC standards. This group recommended three areas for future emphasis in teaching and professional development.

1. Strongly support a continuous and coherent program of professional development, beginning with undergraduate education and continuing to the end of the teacher's career.
2. Recommend that national standards, from NRC or others, provide a common vision of science teaching and learning for K-12 and higher education that all can rely upon to guide the development of teaching practices.
3. Recommend that as programs based on the standards are implemented, teachers be given sufficient time and resources to provide the opportunities for students to achieve the content standards.

Critique of Content Standards

Facilitator: Roger Bybee, Biological Sciences Curriculum Study

Concerns regarding the NRC content standards were summarized in the following five areas.

1. There is some confusion between what constitutes standards and curriculum. In particular, how are these standards to be implemented in the classroom—what are the details, where are the support materials.
2. There were concerns about integrating and coordinating the math, physical sciences, and life sciences in the classroom; teachers need some clear strategies to accomplish the variety of content goals, otherwise the curriculum will become too crowded.
3. Teachers at both the K-12 level and the college level are concerned that the standards may not be meaningful, that, in the end, the students still may not know the material. There is still a need to make the material compelling, challenging, and to offer strategies that ensure learning and retention of the information, as well as the process of acquiring the information.
4. There are concerns that the details would become a national curriculum and that students would be tested on those items. The group recommended that teachers be given bullets to highlight key concepts, rather than details, which are too controlling. For example, details such as:

    > "In all organisms, information is carried in a molecule called DNA, which is a polymer, made up of bases A,G,C, and T. Changes in DNA (which is mutation) occur spontaneously at low rates . . ."

    should be simplified to conceptual bullets which offer more flexibility. So the above details become:

    > "Heredity requires . . .
    >
    > - information
    > - replication of information
    > - and so on . . ."

    If the teacher needs to provide more information, they can use the bullets as guides or benchmarks.
5. Concern about standards becoming stifling also emerged. In particular, should these goals be called "standards" or "recommendations," and how will these standards evolve over the years?

Critique of Assessment Standards

Facilitator: Audrey B. Champagne, University at Albany–State University of New York

The goal of assessment is to measure student attainment. Assessment is not synonymous with testing, it is a process.

Conclusions

1. Assessment plays a central role in educational reform.
2. Quality assessment is expensive in terms of time, money, facilities, and teacher education.
3. Assessment must measure total student attainment, including various aspects not usually measured.

Recommendations

1. Proposed changes in curriculum need to be reflected in assessment; i.e. assess not only what students are expected to learn, but also assess their opportunities to learn.
2. Resources should be appropriately chosen and provided for schools, teachers, and students.
3. All facets of achievement should be assessed with appropriate instruments.
4. The public, including parents, university administrators, and others should be educated regarding the validity and acceptability of these new forms of assessment.
5. Science education reform needs a single focal point, and Sigma Xi should provide this leadership.

Appendix B

Poster Abstracts

In an effort to encourage networking and the dissemination of successful science education programs, two forum poster sessions were held during the two-day meeting. A total of 72 posters were presented. The name of each contact person is marked with an asterisk; addresses and phone numbers are provided.

Poster Abstracts

1 SEMEDS (SCANNING ELECTRON MICROSCOPE EDUCATORS), Katie E. G. Thorp* (University of Dayton Research Institute, 300 College Park, Dayton, OH 45469-0168), Joe Williams (Patterson Career Center, 118 East 1st Street, Dayton, OH 45012), and W. Wade Adams (Wright Laboratory, Materials Directorate (WL/MLPJ), Wright-Patterson AFB, OH 45433-7702). Contact Phone: 513-255-1138.

SEMEDS is a motivational science program which was initiated in 1989 at the Air Force's Wright Laboratory, Aeronautical Systems Center. The program utilizes hands-on experience with high power scanning electron microscopes to stimulate students and demonstrate that science is fun. The program is run by employees at the laboratory who volunteer their own time to assist the students on the microscopes, explain the chemistry, physics and materials science involved, provide possible explanations for features observed with the microscopes, and describe their own education and jobs as scientists, engineers, and technical managers. Teachers from area junior and senior high schools bring students after school hours to the laboratory. The students are divided into groups of three to six and assigned a microscope. Each microscope is monitored by an experienced operator who assists the students and provides explanations. Enthusiasm and personal testimony by teachers and students have demonstrated the success of this rapidly growing program.

2 MICROTECH: MICROSCOPY TECHNICIAN TRAINING PROGRAM, Joe Williams (Patterson Career Center, 118 East 1st Street, Dayton, OH 45012), Katie E. G. Thorp (University of Dayton Research Institute, 300 College Park, Dayton, OH 45469-0168), and W. Wade Adams* (Wright Laboratory, Materials Directorate [WL/MLPJ], Wright-Patterson AFB, OH 45433-7702). Contact Phone: 513-255-2110, ext. 3171.

Recognizing the need for modernization of vocational training and to provide the U.S. with a more highly skilled pool of technical workers, researchers at the Air Force's Wright Laboratory, Aeronautical System Center formed a partnership with local schools to establish a high school vocational training program in microscopy. Utilizing equipment donated by government labs and private industry, a laboratory was established at the local urban vocational school to provide training needed for immediate job placement of students. A former contract employee at the Wright Laboratory became a full-time instructor at the school. Student enrollment is quickly growing and utilization of the equipment by other teachers and classes looks promising. While enrolled in the program, students will be required to analyze and report on a variety of samples which will be supplied by teachers from across the district. These reports can then be used by the teachers to supplement their science curricula. Obtaining projects and completing formal reports will require development of marketing and publication skills by the students.

3 GEMMA: GROWTH IN EDUCATION THROUGH A MATHEMATICS AND SCIENCE MENTORSHIP ALLIANCE, Harvey L. Paige (WL/MLBT, Wright-Patterson AFB, OH 45433-7750) and Sue F. Rinehart* (Alliance for Education, 2100 Kettering Tower, Dayton, OH 45423). Contact Phone: 513-222-2934.

Project GEMMA started in 1990 as a program for teachers of mathematics at all grade levels, with the goal of permitting those teachers to learn first-hand some applications of math in the work place. It has evolved into a multi-faceted program which is now open to teachers of math and science. Secondary school teachers participate in an in-depth work experience in laboratories, industrial facilities, or businesses. These assignments are generally of eight or ten weeks duration. An integral part of the program is a series of seminars wherein teachers learn about the work experiences of other teachers. At the end of the program, teachers present specific "transfer plans" which detail how teachers will take the results of their experiences back into the classroom. These plans are available for use by other teachers. Elementary school teachers participate in week-long seminars held at many sites where secondary school teachers are working. Evaluations of the programs show generally very positive experiences, both for teachers and for mentors.

4 GOVERNMENT-INDUSTRY-EDUCATION COLLABORATION FOR INTELLIGENT TUTOR COMPUTER LABS, Sue Elling (Alliance for Education, 2100 Kettering Tower, Dayton OH 45423), Sue Rinehart* (Alliance for Education, 2100 Kettering Tower, Dayton OH 45423), W. Wade Adams (Wright Laboratory, Materials Directorate [WL/MLPJ], Wright-Patterson AFB, OH 45433-7702), and Katie E. G. Thorp (University of Dayton Research Institute, 300 College Park, Dayton, OH 45469-0168). Contact Phone: 513-222-2934.

Through the dedicated collaborative efforts of many individuals interested in supporting local education, computer laboratories were established at two urban high schools. The purchasing and implementation of the project was handled by the Alliance for Education, a local non-profit education advocate. Funds were supplied by the Air Force as part of a 3-year research activity utilizing artificial intelligence technology to tutor 9th grade students. NCR (now AT&T Global Information Solutions) corporate leaders provided the computers and network equipment at a considerable savings to the project. Each lab is a state-of-the-art facility with air-conditioning, carpeting, special computer tables, computer projection screens, and on-site technical support. Student and teacher enthusiasm toward the project has been gratifying and quantitative results are currently being evaluated for both attitude, skills, and state proficiency tests.

5 THE ST. CATHERINE'S SEA TURTLE CONSERVATION PROGRAM: MODELING EFFECTIVE SCIENCE EDUCATION THROUGH CONSERVATION AND RESEARCH PARTNERSHIPS, Nancy Brannen March, Middle Grades and Secondary Education; and Gale Bishop*, Department of Geology and Geography (Georgia Southern University, Box 8149, Statesboro, GA 30460-8149). Contact Phone: 912-681-5361; FAX: 912-681-0668.

Georgia school teachers served eight to ten day internships as research colleagues on St. Catherine's island, Georgia. Interns monitored daily nesting activity, evaluated possible nests, validated egg chambers, screened the nests, and monitored each nest daily and assessed hatching success by excavation upon emergence of hatchlings. This real-world, hands-on holistic field experience immersed school teachers in the problems of executing a natural history conservation project integrating scientific content and methodology, mathematical analysis, and computer documentation. Outcomes included increased scientific inquiry, reduced science anxiety, heightened self-confidence, and enhanced credibility with students and colleagues. This educational model is applicable to many areas and problems.

6 SIGMA XI AND U.S. ARMY SCIENTISTS: AN INNOVATIVE PARTNERSHIP FOR SCIENCE EDUCATION, Armand V. Cardello* (Behavioral Sciences Division, Science and Technology Directorate, U.S. Army Natick Research, Development, and Engineering Center, Kansas St., Natick, MA. 01760-5020). Contact Phone: 508-651-4720.

The Natick Chapter of Sigma Xi, the U.S. Army Natick R,D&E Center and the U.S. Army Research Institute for Environmental Medicine have established a multifaceted program of science education and outreach to local schools. This program provides support to state, regional and local science fairs; mentoring of students; class lectures and demonstrations; science minicourses; teacher-for-a-day programs; technical tours; and laboratory research opportunities. These activities are facilitated by partnership agreements with school systems and by several U.S. Army-sponsored programs to foster science, mathematics and engineering education. Processes have been developed to engender interests of scientists, to encourage school and student participation, to build partnerships, and to coordinate outreach activities. This program is one of several U.S. Department of Defense programs designed to augment national science, mathematics, and engineering education.

7 AN ALLIANCE BETWEEN UNIVERSITY SCIENTISTS, TEACHERS AND INDUSTRY WITH AN INITIAL FOCUS ON BIOTECHNOLOGY, Christopher Cullis* (Case Western Reserve University [CWRU], 10900 Euclid Avenue, Cleveland, OH 44106-7080). Contact Phone: 216-368-5362.

A collaboration initiated in 1989 between Judy Lachvayder and Chris Cullis in response to an application for a Christa McCauliffe Fellowship has grown into a substantial program. A one week course in biotechnology, using the Cold Spring Harbor Vector van, was run in 1990. A similar one week summer course was run by Cullis for high school freshmen and sophomores. Both programs (teachers and students) have continued with support from the Edison Biotechnology Center (EBTC), U.S. Biochemical, the Howard Hughes Medical Institute and CWRU. A core of teachers from these courses were brought together by the EBTC and the Cleveland Regional Area of Biologists (CRABS) was formed. This group holds regular meetings and develops new classroom exercises. A group of master teachers from the participants have also held their own workshop programs at local and national meetings. A Science and Society Symposium was held in February 1994 and an equipment loan program for teachers has been established. The students who attended the programs are being tracked to determine if they continued their careers in science.

8 SCIENCE MENTOR PROGRAM AT MISSION HILL JUNIOR HIGH SCHOOL, Kam Dahlquist* (225 Sinsheimer Laboratories, University of California, Santa Cruz, CA 95064). Contact Phone: 408-459-0832.

Science graduate students from the University of California at Santa Cruz mentor a class of 7th graders from the Mission Hill Junior High School. The program's purpose is: 1) to create a scientific learning community where scientists interact at different levels of the educational hierarchy; 2) to have fun in order to spark interest in science; and 3) to support girls and minority students in science. A total of seven mentors met with the students at least once a week after school for one quarter to tutor and assist with science fair projects. Other activities included a field trip to a university earth science lab, judging the science fair, and assisting during laboratory exercises. Graduate students run the program with minimal organization and funding, communicating by electronic mail. An informal evaluation of the program by the mentors has concluded that the most valuable and effective activities have been the field trip and assisting with labs. The actual "mentor meetings" after school did not work effectively because they had a vaguely defined purpose and the kids did not show up regularly to participate. Future directions include redefining ourselves as mentors for the entire school instead of just one class and better coordinating our activities with the teachers' curriculum. We will continue to assist with the labs and organize formal tutoring for students having problems with math and science. Finally, we will arrange more activities and field trips such as an amateur astronomy night. We will especially target girls who attended the "Expanding Your HorizonsTM in Science, Mathematics, and Engineering" career day for those activities.

9 CITYLAB, A BIOTECHNOLOGY LEARNING LABORATORY FOR HIGH SCHOOL TEACHERS AND STUDENTS AT THE BOSTON UNIVERSITY SCHOOL OF MEDICINE, Carl Franblau, Constance Phillips*, Doug Zook, Leslie Wolfe, and Don DeRosa (80 E. Concord St., S215, Boston, MA 02118). Contact Phone: 617-541-5629.

CityLab is a fully equipped biotechnology learning laboratory for high school students and teachers funded by the National Institutes of Health and located at the Boston University School of Medicine. The aim of CityLab is to provide access to state-of-the-art laboratory facilities and curriculum in biotechnology otherwise unavailable to most school systems. Teachers bring their classes to CityLab where they are challenged to solve problems by applying the same techniques and concepts of genetics and molecular biology. Each topic is presented in a mystery format. Some popular investigations include *The Mystery of the Crooked Cell* (sickle cell anemia), *The Case of the Crown Jewels* (DNA restrictions analysis), and *Entangled in the Web* (transformation). In addition to regular class visits, CityLab offers two after school enrichment activities, the Biotechnology Club and BioCity. The club provides eighty young people with the opportunity to work more extensively in the laboratory investigating topics such as genetic engineering, gene cloning, and AIDS. BioCity is a mock biotechnology company run by and for students. Since 1992, more than 2,000 high school students and 300 teachers have used CityLab.

10 NORTH CAROLINA SCIENCE AND MATHEMATICS ALLIANCE, Denis T. DuBay* (North Carolina Science and Math Alliance, 410 Oberlin Road, Suite 306, Raleigh, NC 27605). Contact Phone: 919-733-9161, FAX: 617-541-5621.

The Alliance catalyzes building relationships among schools, parents, teachers, businesses, universities, and community colleges, government, and community leaders. A network of nine Regional Partnerships help communities build capacity to reform and support science and mathematics education, school by school. They assess needs, identify resources, and plan and coordinate activities using those resources to solve problems. Partnerships coordinate restructured systems of delivery of teacher education and student instruction in science and mathematics, such as site-based workshops for faculties; community-supported school improvement programs; professional development for school-based teams in leadership and in science and mathematics content; and computer networking applications.

11 ZOOLOGY, EVOLUTION, AND ECOLOGY FOR ELEMENTARY TEACHERS IN A MODEL ALLIANCE BETWEEN A UNIVERSITY BIOLOGY DEPARTMENT AND A ZOO, Ernest F. DuBrul* (Department of Biology, University of Toledo, Toledo, OH), Norma Lewis (Toledo Zoo, Toledo, OH), and Pauline Mesteller (Toledo Public Schools, Toledo, OH 43606). Contact Phone: 419-537-2289. Supported by Eisenhower Grants OBOR #9-61, 0-65, 1-76, and 2-83.

Many of the goals and performance objectives for elementary science deal with hands-on experiences such as observing the characteristics of living things, sorting and classifying, and measuring and recording data. Ideal environments for learning episodes that can foster these objectives are zoos and parks or nature preserves. This poster describes a program that uses the University faculty, local master elementary teachers, and Zoo staff and facilities to: 1) educate K-6 teachers about zoology, ecology, and evolution, 2) provide practical, on-site learning exercises as examples of how teachers can develop zoo visits that will be true learning experiences, 3) help the participants develop zoo-related exercises of classroom use, 4) show the participants the behind-the scenes work that goes on at a zoo, and 5) establish a close rapport between the teachers and a large group of professional resource persons. We present the results of evaluations and follow-up interviews, and we note the key features of this program and suggest how our experience may be used by other partnerships.

12 SCIENCE ALLIANCE: A SCIENTIST/TEACHER PARTNERSHIP, Irene Anne Eckstrand* (National Institutes of Health, 5333 Westbard Ave. Room 918, Bethesda, MD 20876). Contact Phone: 301-594-7762.

Science Alliance, sponsored by the National Institutes of Health, involves fifty NIH scientists, teachers in six elementary schools, and two school districts. The goals are to: 1) support teachers and schools as they develop science programs; 2) provide role models for students; 3) illustrate what scientists do; and 4) encourage a multidisciplinary approach to learning. Activities include classroom visits, workshops on hands-on science for teachers and scientists, a scientist training program, an electronic bulletin board, a workbook of activities that scientists have developed for classroom visits, and a newsletter. Aided by an annual evaluation, we have identified several elements critical to the success of Science Alliance. Teachers and scientists need a good personal relationship; good communications are fundamental. The responsibilities of participants must be clear, and both scientists and teachers need support and encouragement from their supervisors.

13 SHENANDOAH ELEMENTARY SCIENCE ENRICHMENT PROGRAM, Patti Garrett (Shenandoah Elementary School, 5256 North Raider Road, Middletown, IN 47356). Contact Phone: 317-354-6636.

Shenandoah Elementary School is a rural educational facility located in the farmlands of Indiana. The Elementary Science Enrichment Program was established to create a learning atmosphere that encourages scientific thinking and problem-solving. Its inception was founded on the belief that the concepts and process skills inherent in the teaching of science are critical to the early intellectual development of elementary students. The program was established through speaking engagements at the local and state level which resulted in the necessary support to insure its continuation. All students in grades K-5 meet for weekly science activities in our elementary lab to investigate many exciting curricular areas including planaria regeneration, star life cycles, and acid rain telecommunications. This allows for in-depth exploration of the science process skills which culminate in a variety of products including student portfolios, hands-on assessments, simulations and global data communications. These activities are extended through family science and the modeling of science instructional techniques for classroom educators.

14 IMPROVING ELEMENTARY SCIENCE LABORATORIES IN THE CITY OF MEMPHIS SCHOOLS: A PARTNERSHIP BETWEEN THE UNIVERSITY OF TENNESSEE, MEMPHIS, AND THE MEMPHIS BUSINESS COMMUNITY, Karen A. Baskerville[1], Arthur M. Geller[2]*, Eldridge F. Johnson[1], and Jesse F. McClure[3], (Department of Anatomy and Neurobiology[1], Department of Biochemistry[2], and University of Tennessee Administration[3], The University of Tennessee, Memphis, 800 Madison Ave., Memphis, TN 38163). Contact Phone: 901-448-4348.

A goal of the Memphis 2000 project is "to improve science education in the elementary schools by joining businesses together with science and mathematics teachers to provide real-life classroom experience. We have initiated a project to support science laboratories in the elementary schools. Two inner city schools were selected as models. One school had a science teacher, but no laboratory, and was given support and supplies to set up a science laboratory. The second school had a science lab, but no teacher, and was supplied with a graduate student who worked part-time designing and teaching science labs for the fourth, fifth, and sixth grades. The Gordon School Program has worked well, allowing each student to have one hands-on laboratory weekly, and an increased focus on science education. This project recently entered a new phase with the addition of eight more student volunteers. Currently labs are being offered to all students in the second through the sixth grades. The students are working closely with the teachers, with a long-term goal of helping the teachers develop the skills to teach labs independently. We have strong support from the school administration. Long-term goals include increasing the number of volunteers to include members of our Sigma Xi Chapter, retired faculty from the University of Tennessee, and retired scientists and engineers living in Memphis.

15 SCIENTISTS AND EDUCATORS FACILITATING SCIENCE EDUCATION THROUGH SCHOOL-BASED FAMILY LEARNING PROGRAMS, Jeff Goldstein* (Laboratory for Astrophysics, National Air and Space Museum, Washington, DC 20560), Louisa Sheldon, Robert Davis (New Opportunities in Animal Health Sciences [NOAHS] Center, National Zoological Park, Washington, DC 20560), Martin Herbst (M.W. Herbst Consultants, Upper Marlboro, MD 20772), and Pat Petrella (Friends of the National Zoo [FONZ], National Zoological Park, Washington, DC 20008). Contact Phone: 202-357-4933, FAX: 202-633-8174.

Last year the National Air and Space Museum (NASM) and National Zoological Park (NZP) co-sponsored an educational outreach experiment, *Learning is a Family Experience* (LiFE). LiFE's goal was to create friendly bridges to science and technology for forty-seven local area elementary and middle schools with a high proportion of minority and/or low income students. LiFE provided a school-based family field trip, within a framework of classroom activities. Scientists and educators used the space sciences in an interdisciplinary framework, to teach young and old the process of science. The program, mated to the curriculum, included five elements: teacher in-servicing; a donation package to the schools; a special evening at the NASM for students, parents and teachers; pre-and post-visit activities; and program assessment. We will report on exit questionnaire data, identify scientific/educational partnerships.

16 KINDLING AND REKINDLING THE FLAME THROUGH RESEARCH, Thomas A. Gorrell, Director, Hughes Undergraduate Biological Sciences Education Grant; C.W. Miller, Director, National Institutes of Health Science Motivation Program; and Lynn D. Butler*, Assistant to the Directors (Colorado

State University [CSU], College of Natural Sciences, Fort Collins, CO 80523). Contact Phone: 303-491-1433.

The goals and objectives for the Hughes High School Scholars, Science Motivation Program and Hughes/NIH Research for Teachers programs have been integrated to provide common experiences, even though they are funded from separate sources. High school juniors with a strong interest in the biomedical sciences and secondary school biology and chemistry teachers have the opportunity to become active members of a research team at CSU. Life sciences faculty members act as mentors during the research experience and provide topical research project opportunities. Participants are required to write a scientific research paper and present an oral report. Students and teachers are exposed to the complete scientific process by actually "doing" science and reporting their results. From these experiences, students gain an enthusiasm for going to college and promote science and research as potential career goals. The teacher participants indicate they become rejuvenated to return to the classroom with many new ideas for classroom activities. They maintain connections with their mentors and become strong promoters for Colorado State University and for life sciences research. These programs kindle the interest of high school students and rekindle the flame of teachers toward teaching, research, and the scientific process.

17 DISCOVER SCIENCE: HANDS-ON SCIENCE WORKSHOPS FOR ELEMENTARY TEACHERS AND SUMMER SCIENCE CAMPS FOR ELEMENTARY STUDENTS, Louis Gotlib* (South Granville High School, P.O. Box 398, Creedmoor NC 27522), Ernest Bibby (Granville County Schools, P.O. Box 927, Oxford, NC 27565), and Bob Cullen (NC Science and Math Alliance, 410 Oberlin Rd. Suite 306, Raleigh NC 27605). Contact Phone: 919-528-1507, FAX: 919-528-3389.

Teams of local mentor teachers (assisted by college students in the NC Teaching Fellows Program) run week-long workshops for elementary teachers (at four sites in 1993, six in 1994). Major funding for the camps is provided through The Glaxo Foundation, supplemented with local funds. The workshops focus on hands-on science (using inexpensive materials) and provide familiarity and experience with the new NC science curriculum and assessment program. The use of local resources is stressed (including visiting scientists and readily available store-bought materials). Each camp has its own theme and provides teachers with a variety of resources to be used with students of all abilities. The mentor teachers then run week-long, all expense paid, non-residential science camps for elementary students (open to all students, but with females and minorities as target groups). Students take part in long- and short-term projects, working individually and in groups. Pre and post participation surveys of all participants were conducted and analyzed, with favorable results for both the student and teacher weeks. Additional activities include parent nights, and follow-up workshops. Eighty-nine teachers and 208 students participated in 1993.

18 TRAVELING SCIENCE: AN ELEMENTARY SCIENCE ENHANCEMENT PROGRAM, Louis Gotlib*, Steve Brown (South Granville High School, P.O. Box 398, Creedmoor NC 27522) and Ernest Bibby (Granville County Schools, P.O. Box 927, Oxford, NC 27565). Contact Phone: 919-528-1507, FAX: 919-528-3389.

Traveling Science is an elementary science visitation program by two high school teachers (using scheduled release time) for every third to fifth grade student and teacher in Granville County, North Carolina (a total of sixty-one classes, 1,600 students—over 25,000 student contacts in three years). Teachers and students see and participate in hands-on, inquiry-based science done with inexpensive, readily available materials (usually less than $2 per class). Teachers become more confident and self-reliant with respect to science education, and students get increased exposure to hands-on science. In addition to the classroom visits (a total of six per year for each class), teachers receive a guide containing introductory and follow-up materials, and a monthly newsletter. Visit topics cover the physical, life and earth sciences; designed to stress the processes of science. We try to use topics of interest and relevance to students, such as toys, food, animals and playground activities. Teachers and schools also receive additional materials (posters and videos).

19 PUTTING THE SCIENTIST IN SCIENCE EDUCATION, John P. Greene* (Physics Division, Argonne National Laboratory, 9700 S. Cass Avenue, Argonne, IL 60439). Contact Phone: 703-252-5364, FAX: 708-252-6210.

A personal account is given of some of the ways scientists could get involved in science education at the local level. Being employed at a National Laboratory such as Argonne presents a myriad of opportunities and programs involving the educational community. There have been basically, three areas of involvement at present, through our Division of Educational Programs (DEP), through initiatives presented in conjunction with the Argonne Chapter of Sigma Xi and a volunteer effort with the Museum of Science and Industry of Chicago, Scientists, and Schools Program. Some descriptions of these efforts will be outlined from a personal perspective, and hopefully a measure of the impact gained by the scientists' involvement in the education process.

20 SCIENCE AND ENGINEERING CAREERS THROUGH APPRENTICESHIPS, G. Hanselmann, E. Hofer*, A. Krumdieck. Swiss Club of Sigma Xi, Mornets 29, 2520 La Neuveville, Switzerland. Contact Phone: 41-38-51 44 78.

There is no academic degree in Switzerland equivalent to the Bachelor's degree awarded by universities in the United States. Many jobs requiring a B.S. in the U.S. are filled in Switzerland by those who have completed an appropriate apprenticeship. Such jobs include laboratory technicians, chemical, physical or technical assistants in industry, technicians in health care and applied sciences, and electronic data processors. The academic route of a research scientist begins with 5-6 years of primary school followed by 2-4 years of secondary school. Then come 4 1/2-6 1/2 years of university preparatory education called *gymnasium* or *lycée*, culminating in a *matura* examination. Then comes matriculation at a cantonal university or federal technical institute for 5-8 semesters (approximate equivalent of M.S.) and 4 or more additional semesters for a doctorate. Recent changes make it possible to take a normal apprenticeship (3-4 yr) after secondary school and then to pursue additional studies to pass a professional or trade *matura* exam. Recipients of this *matura* have access to any Swiss regional technical institute for training in engineering, after which they may take an entrance examination to enter the Federal Technical Institute.

21 EXPERIENCE THE NATURAL SCIENCES: PROGRAMS FOR TEACHERS AT THE UNIVERSITY OF HAWAII AT HILO, Marlene Nachbar Hapai* (Natural Sciences Division, University of Hawaii at Hilo, 200 W. Kawali St., Hilo, HI 96720-4091). Contact Phone: 808-933-3361.

Since 1988, the University of Hawaii at Hilo Science and Education faculty have jointly created programs for pre- and in-service teachers to improve science teaching, to increase the number of science teachers, and to improve scientific literacy in the general population. The National Sciences major, approved in 1991, with both elementary and secondary teaching options, has gone from three degree seeking candidates in the fall of 1991 to fifty-nine in the spring of 1994. The major provides elementary teachers with a general science degree and teaching certification; and secondary teachers with a more intense general science degree, a specialized minor, and teaching certification. Additionally, a new 18 credit Natural Sciences Certificate for in-service elementary teachers, designed to enhance their scientific background and classroom methodology, has already attracted over 250 teachers within the last year.

22 BEAMS—BECOMING ENTHUSIASTIC ABOUT MATH AND SCIENCE—A DEPARTMENT OF ENERGY RESEARCH LABORATORY/SCHOOL DISTRICT PARTNERSHIP PROGRAM, Beverly K. Hartline, Kathryn Strozak, and Steve Gagnon* (CEBAF, 12000 Jefferson Avenue, Newport News, VA 23606). Contact Phone: 804-249-6286.

BEAMS immerses fifth and sixth grade classes in CEBAF's environment for a week of school. By exposing students and teachers to science's excitement, challenges, and opportunities, BEAMS motivates students, enhances teachers, and involves parents, with the goal of improving scientific literacy and work force readiness. CEBAF and its school partners are extending BEAMS into a multi-year program, integrating educational partnerships active in the region. The planned focus emphasizes grades four through ten. A long-term evaluation model, incorporating measures of students attitudes, achievement, and academic course choices is being implemented. Three years of data on student attitudinal changes, referenced against controls, have been analyzed.

23 FORD RESEARCH LABORATORY HIGH SCHOOL SCIENCE AND TECHNOLOGY PROGRAM (HSSTP), Kenneth C. Hass* (Ford Motor

Company, Scientific Research Laboratories MD-3028, Dearborn, MI 48121-2053). Contact Phone: 313-322-0098.

Since 1984, the Ford Motor Company Research Laboratory has offered a series of Saturday morning enrichment experiences and summer work opportunities for high school students and teachers. The goal is to increase awareness of technical careers and the importance of science and mathematics in industry. The Saturday sessions are run entirely by volunteers and are organized around current topics ranging from fundamental science (e.g., atmospheric chemistry) to advanced engineering and manufacturing (e.g., glass production). A typical session includes a lecture, laboratory tours and demonstrations, a refreshment/social break and a hands-on activity whenever possible. Over 500 students and teachers participate annually from over 120 area high schools. Nearly one third of the students are minorities from the city of Detroit. Session quality is monitored through feedback from participants and volunteers. Juniors and seniors who attend at least three sessions are eligible to compete for four-week summer internships. Typically, about twenty-five to thirty interns (out of forty to fifty applicants) are selected on the basis of a transcript, teacher recommendation and a 2500-word report on a technical topic. Ford also generally hosts about eight summer teacher fellows through a statewide program that began as an HSSTP initiative. The HSSTP was recently recognized by the Industrial Research Institute as one of eleven "Winning [Pre-College Education] Programs" nationwide. Keys to success include strong grassroots and managerial support and extensive networking in the community.

24 CARROLL COUNTY HANDS-ON ELEMENTARY SCIENCE, Helen G. Herlocker*, National Diffusion Network Project Director (P.O. Box 661, Hampstead, MD 21074) and Gary L. Dunkleberger, Director of Curriculum and Staff Development (Carroll County Public Schools, 55 N. Court Street, Westminster, MD 21157). Contact Phone: 410-374-1358.

Carroll County Hands-on Elementary Science is a nationally recognized Elementary Science Curriculum which has been disseminated in forty states, Puerto Rico, The Virgin Islands, Saipan, and Samoa. The curriculum is a non-textbook, process-based, constructivist approach to teaching science. Unique features of this curriculum include its teacher-written daily lesson plan format, its complete kit of science supplies, and its complete set of Spanish materials. In order to be included by the National Diffusion Network, Hands-on Elementary Science collected data to support the following claims: the program enhances teacher and student attitudes toward science; the program changes both the amount and the type of science instruction; the program is adaptable and transportable; the teacher training component is effective. The poster display will feature sample activities, data which demonstrates the effectiveness of the staff development plan, and samples which show the degree to which the program supports selected state curriculum frameworks.

25 MODELING SCIENCE AND MATHEMATICS REFORM IN THE ELEMENTARY CLASSROOMS OF NORTHEAST IOWA, Darrell Hoff*, Department of Physics; Wendy Stevens, Department of Biology; Joyce Becker, Mathematics Department; and Nan Eklund, Education Department (Luther College, Decorah, IA 52101). Contact Phone: 319-382-1087, FAX: 319-387-1080.

Luther College is coordinating a cooperative demonstration project involving schools in northeast Iowa involving area school districts, the Keystone Area education agency and other area colleges and industries. We will establish ten elementary classrooms staffed by master teachers who will provide demonstration classes designed to meet the goals of the AAAS Benchmarks and the NCTM Standards. An intense summer experience to review these national reform efforts will be held in 1994. The master teachers will also select or devise lessons and activities best suited to meet the national standards. Classroom visits by other teachers to these demonstration classrooms will be supported by local Eisenhower funds. An estimated 800 teachers will visit these demonstration classrooms during the 1994-95 school year.

26 RX FOR SCIENCE LITERACY: THE WHAT, WHERE, HOW, AND WHY OF HEALTH SCIENCE RESEARCH (A TEACHER'S MANUAL ABOUT BIOMEDICAL RESEARCH, Karen S. Hoffman* (North Carolina Association for Biomedical Research, Box 25459, Raleigh, NC 27611-5459). Contact Phone: 919-829-3911.

When the North Carolina Association for Biomedical Research (NCABR) surveyed the state's science teachers in March 1993, 92% of those responding requested information related to biomedical research. Most of the teachers requested lesson plans and activities designed to help them give students an accurate and balanced perspective on research. In response to that need, NCABR has recently completed production of a 300-page teacher's manual that provides an overview of the biomedical research process and describes the role and care of animals in that process. *Rx for Science Literacy* incorporates background information, lesson plans, handouts and activities to assist teachers in K-12 classrooms. Developed by a science teacher with assistance from science and education experts, the manual captures the complex biomedical research process in an easy-to-follow, easy-to-use format. The manual is intended to be presented to teachers in a workshop format. In North Carolina, NCABR plans to begin these workshops in fall 1994. The workshops will include a tour of a biomedical research laboratory and on-site presentations by bench scientists. Teacher evaluation of the manual will be structured into the workshop program. The manual is available at cost to all interested individuals and organizations.

27 EARTH SYSTEMS EDUCATION: REPORT FROM 60 U.S. TEAMS, William H. Hoyt* (Department of Earth Sciences, University of Northern Colorado, Greeley, CO 80639), Victor J. Mayer (Earth Systems Education Program Office, 059 Ramseyer Hall, 29 West Woodruff, The Ohio State University, Columbus, OH 43210), Raymond L. Tschillard (The Laboratory School, University of Northern Colorado, Greeley, CO 80639), and Rosanne W. Fortner (Earth Systems Education Program Office, 059 Ramseyer Hall, 29 West

Woodruff, The Ohio State University, Columbus, OH 43210). Contact Phone: (303) 351-2487.

Efforts are now underway to radically change the content and organization of the K-12 curriculum. Earth Systems Education is consistent with "Project 2061" (AAAS), "Scope, Sequence, and Coordination" (NSTA), and the emerging "National Science Standards" (NRC), but differs in that the focus is systems science of planet Earth, especially as it connects to all areas of the curriculum. NSF has supported about 200 teachers along with school administrators and college professors from leadership teams to pilot reform and restructuring efforts tailored to needs of local districts and states. Evaluation of Earth Systems Education has been undertaken by Horizon Research, and a clear conclusion has emerged that teacher/school administrator/college professor teaming and support over several years within a local school district is most effective at encouraging significant school curriculum and structural reform.

28 RURAL SCIENCE EDUCATION PROGRAM, Clare Intress*, (New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, NM 87104-1375). Contact Phone: 505-841-8837.

The Rural Science Education Project is an outreach program of the New Mexico Museum of Natural History and Science with the goal of helping rural elementary schools improve science teaching and learning by using local natural environmental resources. This program is based on the assumption that rural schools, so often described as disadvantaged in terms of curricular resources, actually provide a science teaching advantage because of their locale. The natural environment of mountains, forests, ponds, desert, or fields offers a context for the study of scientific concepts and skills that appeals to many youngsters. To tap these resources, teachers need access to knowledge about the rural school locality's natural history. Through a process of active participation in school-based workshops and field site studies, teachers observe and learn about the native flora, fauna, geology, and paleontology of their community. In addition, they are exposed to instructional strategies, activities, and provided with materials which foster experiential learning. This school-museum partnership, now in its fifth year, has aided more than 800 rural teachers' on-going professional development. These educators have, in turn, enhanced science education throughout New Mexico for more than 25,000 students.

29 ENHANCEMENT OF SCIENCE CLASS IN WEST CENTRAL ALABAMA, Jill A. Jenkins*, (U.S. Department of the Interior, National Biological Survey, Southeastern Fish Cultural Laboratory, Marion, Alabama 36756) and Dianne Johnson, (West Side Middle School, Route 14, Box 265-C, Marion, AL 36756). Contact Phone: 205-683-6175.

Although the primary mission of the Southeastern Fish Cultural Laboratory is to conduct scientific research on the problems facing the aquaculture industry, other goals are technology transfer and education. Over the past two years, a successful educational outreach program has been established with a local middle school. After a letter extending educational support to the public schools was written to the Superintendent, one teacher with her many science students began making monthly trips to the facility in order to gain hands-on experience in aquaculture science. The county supports the effort by providing the bus transport of thirty miles round trip. Students conduct a long-term experiment in fish growth while also learning about waterfowl, the environment, and the aquaculture industry. They are engaged in projects involving some hands-on experience. This program was judged to be successful due to: a) participant number increased from fifty to eighty by the second school year, b) students display more inquiry skills and aggressive learning attitudes not seen previously, and c) students have achieved better cooperative learning skills.

30 CELEBRATING SCIENCE TOGETHER: HANDS ON COOPERATION, K-8 COLLEGE, Dorothy A. Jones* (Biology Department, St. Joseph's College, Rensselaer, IN 47978); Edward Habrowski (Education Department, St. Joseph's College, Rensselaer, IN 47978); Maria Dalhoumi (School City of East Chicago and Education Program, Calumet College of St. Joseph, 2400 New York Avenue, Whitting, IN 46394). Contact Phone: 219-866-6111.

Underserved school children in northwest Indiana, K-8, receive higher quality science teaching by consortial cooperation among St. Joseph's College area school corporations, and Calumet College of St. Joseph. In 1993-94, new science lessons will be taught and assessed for 1,350 students in the following corporations: Rensselaer Central Schools, School City of East Chicago, Diocese of Lafayette-in-Indiana & Gary Diocese. Student science learning is measured by teacher-defined benchmarks correlated with science proficiency goals. Project impact is assessed through teacher, peer advisor, and coordinator observations and site visits. The Coalition is supported by the Indiana Commission for Higher Education TII and Eisenhower programs.

31 THE SCIENCE OUTREACH PROGRAM, Bonnie Kaiser*, (The Rockefeller University, Box 53, 1230 York Avenue, New York, NY 10021). Contact Phone: 212-327-7431.

High school juniors and seniors are recruited to gain research experience. They write research reports, present journal articles and attend laboratory meetings. Public and private funding is available for a fraction of the more than fifty students who work during the summers. Precollege science teachers are funded by private and public sources to spend two summers doing laboratory research with faculty to then translate that experience into active learning for students and colleagues. They write research reports and present action plans, with budgets, to a committee of faculty, senior teachers, and noted educators who also perform program assessment. Some initial teacher successes: 1) Increase from 7 in 39 to 24 in 43 in the number of underrepresented minorities passing Regents Biology and at higher average scores. 2) First time that students have asked if they could do research. 3) Increase from 7 to 9 in number of Westinghouse semifinalists. 4) Creating new curricula, including biotechnology, molecular biology and multimedia science courses for students. 5) Accessing Internet resources and establishing an information technology center for science for teachers and students. 6) Learning new techniques and bringing more laboratory equipment into schools. Thus, mentored laboratory research of teachers aimed at establishing long-term partnerships with their schools does indeed lead to improving science education in concrete ways.

32 A SUCCESSFUL RESEARCH-BASED PARTNERSHIP BETWEEN UNIVERSITY SCIENTISTS AND HIGH SCHOOL TEACHERS, Helen W. Kreuzer*, (Educational Projects Coordinator, North Carolina Biotechnology Center, P.O. Box 13547, Research Triangle Park, NC 27709), Denise L. Woodworth, and Kenneth N. Kreuzer, Department of Microbiology, Duke University Medical Center, Durham, NC 27710). Contact Phone: 919-541-9366.

The goal of this program was to involve students in real-world science through collaboration on a research project with university scientists. The North Carolina Biotechnology Center (NCBC) and a Duke University Medical Center laboratory identified a line of experimentation that was both relevant to the focus of the lab, and technically and intellectually appropriate for the high school setting. The investigations involve restriction mapping of transposon insertions in the genome of bacteriophage T4. Teachers involved in the project were already familiar with restriction analysis through prior attendance at NcBC workshops and the Advanced Placement Biology restriction analysis labs. In summer 1992, NCBC staff and the Duke scientists held a workshop to orient ten teachers to the project and prepare materials for analysis by their students. During the school year, a member of the lab visited each classroom and discussed the project. Students conducted mapping experiments and presented their data at a conference in the spring of 1993. Twenty insertions were mapped in the first year. In the 1993 teacher workshop, teachers isolated new mutants and screened them for sensitivity to the anti-tumor drug studied by the Duke group, identifying several mutants of interest. Now in its second year, the collaboration has generated valuable scientific results and inspired independent spin-off activities. Impact on teachers and students has been evaluated through questionnaires.

33 INTEGRATING SCIENCE WITH HUMANITIES - LOOSING THE FEAR OF SCIENCE, Richard W. Lo Pinto*, Biological Sciences; Samuel Raphalides, Political Science and History; Duane Edwards, English Literature) Fairleigh Dickinson University, Teaneck, NJ 07666). Contact Phone: 201-692-2297.

This presentation illustrates the approach and effectiveness of an interactive seminar program for K-12 non-science teachers (funded by the NJ Dept. of Higher Education) aimed at integrating the humanities and science, especially environmental sciences. Teachers become comfortable dealing with the commonality of science, literature, and human culture. In a collaborative format between seminar organizers and K-12 teachers, participants contribute their understanding of literature, history, politics, and culture to develop a new outlook on "environmental awareness" and on pollution's impact on society.

Prehistoric, medieval, 18th century, modern western cultures, Oriental, Native American, and tropical island cultures are explored to shed light upon today's environmental attitudes. This provides a better understanding of the way science, within a cultural context, approaches environmental problems.

34 HANDS-ON ASTRONOMY ACTIVITIES FOR THE ELEMENTARY SCHOOL, Thomas E. Lutz and Jack C. Horne* (Science, Mathematics, Engineering and Education Center, Washington State University, Pullman, WA 99164-4237). Contact Phone: 509-335-4772.

We held a series of astronomy workshops for local school teachers using astronomy activities from a course we give for Elementary Education majors. The school teachers provide us with feedback about successes and failures. Then we try the revised activities in the classroom. Via this in-service and pre-service feedback, the astronomy laboratory activities in the course have been completely revised over the last three years. The activities we use are almost entirely hands-on. The activities include use of a log book (or journal) for describing outside-of-class observations of sunsets, phases of the moon, portable sundial, and the somewhat unique method we use to teach the constellations. In addition, all laboratory activity records are kept in the log book. Laboratory activities cover the use of fists to measure degrees, constellations, phases of the moon, motions of the earth, moon and sun, the seasons, cratering on the moon, relative distances and sizes of planets, Invent an Alien, lenses, images and telescopes, and the making of a comet. In our poster, based roughly on the theme of the seasons, we will describe a portable, multi-user sundial, length of the day display using newspaper data, two temperature/season activities, and a model demonstration of why the sundial shadows behave as they do.

34A DELIVERING HANDS-ON TECHNOLOGY EDUCATION, Ralph Nelson* and Bruce Booth (DuPont Co., P.O.B. 80304, Wilmington, DE 19880-0304). Contact Phone: 302-695-3043; FAX: 302-695-2504.

The Science Alliance serves Delaware and borders of neighboring states. A core group of volunteers and a small paid staff coordinate the technology education needs of K-12 students and their teachers, the time and talent donated by volunteers, and the financial support of local business, and government agencies. In five years we facilitated contact between hundreds of technical professionals and thousands of students. We will provide some details on the diverse elements which secured its success, illustrate typical programs offered, and recommend action directions for prospective groups. The Science Alliance's success is evident from the national publicity it has received, and the large amount of funding it has secured, but most of all by hands-on experiences provided by volunteers and science kits we bought and now routinely loan to teachers.

35 HANDS-ON SCIENCE METHODS CLASS FOR PRE-SERVICE ELEMENTARY TEACHERS, Barbara M. Manner*, (Department of Physics, School of Education, Duquesne University, Pittsburgh, PA 15282). Contact Phone: 412-396-6106.

If elementary teachers are to be comfortable teaching science, they must have positive pre-service experiences. A science methods class that is activity-based and student-centered, rather than lecture-based and teacher-centered, peaks their interest in science and alleviates their fears. Activities conducted by the students illustrate science concepts or integrate science with children's literature books such as *The Grouchy Ladybug*. These activities are conducted by each student with the rest of the class and the professor acting as an elementary class. Each activity is then evaluated as to the science concept, what was done well, and how it could be improved. The students also relate how the activity would be integrated with other subjects such as social studies, art, math, and language arts. Student feedback indicates this method is enjoyable, educational, and valuable in preparing them to teach science. The "oohs" and "I didn't know that!" during activities are positives, but students have also learned some science, lost most of their science anxiety, and will teach science with the confidence and enthusiasm that was lacking at the beginning of the course.

36 DISCOVERY DAY: A COMMUNITY COALITION FOR SCIENCE AWARENESS, Xavier K. Maruyama* and John Sanders (Naval Postgraduate School, Monterey, CA 93943), and Eric Bull (Monte Vista School, Monterey, CA 93940). Contact Phone: 408-656-2431, FAX: 408-656-2834.

This is a science awareness outreach program which drew approximately half a percent of Monterey County's inhabitants for one day of hands-on science activities. Monterey County is about half the size of Massachusetts, but with a relatively small population (376,000). Yet, children from more than 120 rural and urban schools, along with their parents participated in DISCOVERY DAY 1993. Discovery Day is an outgrowth of a 1989 science fair workshop attended by about 60 students. Explosive growth came after changing from a goal-oriented workshop theme to an activity-based hands-on program emphasizing participation, enjoyment and the fascination value of science. Scaled to larger metropolitan areas, this six hour science program drew as many attendees as a professional sports team; the difference for our event being that participants far outnumbered spectators. The event is sponsored by the Monterey County Science and Engineering Fair Coalition, which includes the Monterey County Herald, First National Bank of Central California, Monterey Bay Aquarium, Monterey County Office of Education, Lyceum of Monterey County, Junior League of Monterey County, Naval Postgraduate School and the California American Water Company. The ownership of this event has expanded to a truly community-wide coalition as members of other organizations interested in science education provide activities, experiments and personnel. These include teachers from local elementary, middle and high schools, both public and private, community colleges, staff from the community hospital and the Monterey City Library, members of MOOSE (Monterey Organization Of Science Educators) and the local Sigma Xi Club. Local merchants contributed to insure the success of this science awareness day. It was gratifying to observe that support for science education extended beyond our parochial circle of scientists.

37 SCIENCE ADVISORS IN THE PUBLIC SCHOOLS, L.K. Johnson*, D.I. Rubenstein (EEB, Princeton University, Princeton, NJ 08543), R. Holt (PPPL, P.O. Box 451, Princeton, NJ 08544), and S. Strauss-Debenedetti (E-Quad, Princeton University, Princeton, NJ 08544). Contact Phone: 609-258-3846.

Last September we began a program in which each public school in seven New Jersey districts invited a scientist form the Princeton Chapter of Sigma Xi to serve as Science Advisor. Now, fifty-seven volunteers serve fifty-four schools. Key elements of the program are sustained contact and an integrated network. The Science Advisor visits the school three hours per week to form creative partnerships with teachers that enable the teacher to better convey the process of science. The Advisor is also a teacher's link to expertise and resource, via a formal network. Members of the network (Advisors plus additional volunteers) communicate by e-mail and meet regularly to share ideas and make inquiries on behalf of teachers. At the hub is a paid science Coordinator who organizes information and ideas, and matches requests with resources. Local employers support the program by providing salaried time for employees to be Science Advisors. Training sessions upgrade science advising skills.

38 SCIENTISTS IN THE CLASSROOM: A MODEL INDUSTRY-SCHOOL PARTNERSHIP, Susan C. McKarns[1]*, Nancy Crouch[2], Jo Spach[3], Jo Peay[1], and J. Don deBethizy[1] ([1]Biological Research Division, R.J. Reynolds Tobacco Company, Winston-Salem, NC 27102; [2]Science and Math Alliance, Western Triad Region, P.O. Box 7598, Winston-Salem, NC 27109; and [3]Community Affairs Department, R.J. Reynolds Tobacco Company, Winston-Salem, NC 27102). Contact Phone: 910-741-2122, FAX: 910-741-5019.

Scientists at R.J. Reynolds Tobacco Company (RJR) established a partnership with the Western Triad Region of the North Carolina Science and Mathematics Alliance to successfully sponsor a unique hands-on industry-school education program for more than 300 grade school students. The goal of this initiative was to promote and improve science and technology education in the Western Triad Region of North Carolina by incorporating relevant examples of applied science and technology into the fifth grade classroom. Fifth-grade students and teachers worked directly with RJR scientists to design and implement classroom science and technology projects. The students summarized their efforts into formal scientific poster presentations, and presented them at an evening science symposium held at RJR's state-of-the-art research facility, the Bowman Gray Technical Center.

39 STUDENTS IN THE LABORATORY: A MODEL INDUSTRY-SCHOOL PARTNERSHIP, Susan C. McKarns[1]*, Nancy Crouch[2], and J. Don deBethizy[1] ([1]Biological Research Division, R.J. Reynolds Tobacco Company, Winston-

Salem, NC 27102; and [2]Science and Math Alliance, Western Triad Region, P.O. Box 7598, Winston-Salem, NC 27109). Contact Phone: 910-741-2122, FAX: 910-741-5019.

Scientists at R.J. Reynolds Tobacco Company (RJR) established a partnership with the Western Triad Region of the North Carolina Science and Mathematics Alliance to successfully sponsor a science and technology shadow educational program for local students. The objective of this initiative was to promote and improve science and technology education among female and minority students throughout the Western Triad Region of North Carolina by exposing eighth grade students and their teachers to practical applications of science and technology in the RJR laboratories. Eighth grade students and teachers spent a day touring the laboratories in RJR's research and development facility and visiting with scientists during a routine work day. This enabled students to "shadow" a scientists in an area relevant to the North Carolina eighth grade science curriculum. Students and teachers shared lunch with "their scientists" and everyone participated in a very successful formal panel discussion regarding career potential in the science field.

40 SCIENCE IN MOTION. Michele Anderson, Dave Howe, and Donald Mitchell* (Science In Motion Office, Juniata College, Huntingdon, Pennsylvania 16652). Contact Phone: 814-643-4310, ext. 566.

With the help of grants from the National Science Foundation, the Howard Hughes Medical Institute and other sponsors, we have instituted a program that provides total support for the high school science teacher. Using specially designed vans, certified science teachers deliver modern scientific instrumentation to schools and support the teacher in introducing the students to the use of this equipment. Summer programs and science fairs are available where teachers have the opportunity to use the equipment and develop experiments for their classrooms. The activities of this program offer students and faculty the opportunity to demonstrate the attainment of national standards. This program has been featured on ABC news as a successful program in exciting students about science using a hands-on approach.

41 MASTER'S NETWORK, Ray E. Myers, Professor of Education and MASTER'S Program Director, Shirley C. Riley*, Assistant Program Director, MASTER'S Network (Seattle Pacific University, Seattle, WA 98199). Contact Phone: 206-281-2504.

A state-wide network for Mathematics And Science Teaching Excellence Through Resources, Renewal, Research, and Services. MASTER'S Network is a grant-supported project designed to provide a comprehensive teacher support system for enhancing MST industry representatives, and MST professional societies, a unique feature in the broad alliance of organizations involved. Made up of three inter-related projects, MASTER'S facilitates the provision of resources, services, and opportunities for renewal for the instructional expert. Project One provides support through expert assistance as a cadre of scientists and engineers volunteer to serve as assistants in the classroom. Project Two provides support in the form of math/science summer courses, plus forums throughout the school year to offer ongoing collegial support. Project Three will soon provide support through information with the development of TROL (Teaching Resources on Line), our catalog database of locally available MST resources. The guiding principle of MASTER3S is the belief that by empowering, supporting and serving the teacher, we can most effectively impact student attitudes toward and achievement in MST subjects.

42 ROCHESTER AREA INTERACTIVE TELECOMMUNICATIONS NETWORK (RAITN): A PARTNERSHIP IN ROCHESTER BETWEEN EDUCATORS AND INDUSTRY, Carol T. O'Leary* (NYSERNet/RIT, RIT City Center, 50 W. Main St., Rochester, NY 14614). Contact Phone: 716-475-2984.

Primarily funded by Rochester Telephone Corporation, the RAITN system connects five area high schools, Rochester Institute of Technology (RIT), and State University of New York at Brockport. Monroe#1 Board of Cooperative Educational Services coordinates the interactive programming which may originate from any of the sites. Course offerings on the network range from full credit college courses to high schools sharing unique classes to increase each partners' breadth of educational options. Special events dealing with a variety of interest areas such as teen health issues, professional development, guest speakers and political leaders, and multicultural diversity topics fill out the schedule of interactive programming. "Electronic field trips" allow students and staff to "virtually attend" seminars, science fairs, and teleconferences held at RIT without leaving their schools. Internet connectivity and a new group of high school, university and industry partners are the next additions to the network.

43 WOMEN IN SCIENCE, ENGINEERING, AND MATH MENTORS PILOT PROGRAM, Carol T. O'Leary* (NYSERNet/RIT, RIT City Center, 50 W. Main Street, Rochester, NY 14614). Contact Phone: 716-475-2984.

The Women in Science, Engineering, and Math Mentors Program is a partnership program conducted by New York State Education and Research Network (NYSERNet), Rochester Institute of Technology (RIT) and the Pittsford and Rochester City School districts. The goal of this project is to introduce high school girls to professional women from both educational and industrial scientific fields. The pilot program began in the fall of 1993 with the girls coming to RIT's campus, via the video interactive network or in person, for a careers assessment seminar. Then they carried on "e-pal" relationships via electronic conferencing on the data network to pursue many mentors and a myriad of different career avenues. The questions ranged from simple information requests regarding the requirements for a job to in-depth pursuit of emotional and personal characteristics needed for different professions. The luncheon finale brought us together on RIT's campus to get to know each other face to face. We then toured the Micro-electronics lab and manufacturing facility at RIT. A 1993-94 school year program now involves over 140 mentors and students. We have partnered with other projects in the Rochester area to extend the sharing of the vast resources of our community.

44 HANDS-ON, MINDS-ON, TURNED ON TO SCIENCE IN GRADE SIX, Eldora M. Ondrus*, Eve Suckow, and Linda Christopherson, (Colfax Elementary School, 601 University, Colfax, WI 54730). Contact Phone: 715-962-3676.

The question, "What are we going to do in science today?" gets asked every day in the sixth grade at Colfax Elementary School. The key is "do". Three classroom teachers have made it their common goal to promote interest, curiosity, and love for science in the hope that students will reach for higher level science classes in secondary school. The poster shows students involved in experiments which integrate a variety of subject areas. These include finding mass, working with Cartesian divers, research crystals, making 3-D crystals, solving density problems, and learning about chromatography. Students work either individually or in cooperative learning groups of four to discover answers to their own questions and those posed by their teachers. They keep written records of all their science explorations and discoveries in their science journals. The writing reinforces the concepts discovered as well as the scientific process of recording observations and proposing explanations.

45 RESEARCH AS AN EDUCATIONAL TOOL, Randi Neff*, Dan Perlmutter, Paul Klaczynski, LuJuan Gibson (Western Carolina University, Cullowhee, NC 28723). Contact Phone: 704-227-7158.

Our students have participated in original group research projects focused on the natural environment which culminate in a written manuscript published in-house, and an oral presentation to peers, faculty, and the university community. Our goal has been to develop their critical thinking skills so that they will be more successful in high school and college. We have served ninety-three students (47.1% white, 44.1% black, 5.4% hispanic, 2.2% American Indian, 1.2% asian) from an eight state region in the southeast over the past three years. Thirty-one students have graduated from high school with over 70% enrolled in college and another thirty-four are seniors this year. We are tracking students' progress in college and are developing our own critical thinking test to measure the impact of our program. Although preliminary, the results from the critical thinking test indicated that students are often prone to logical errors; however, higher levels of critical thinking were observed on items which raised issues that conflicted with students' pre-existing beliefs.

46 SMITH COLLEGE SECONDARY MATH AND SCIENCE OUTREACH PROGRAM, Jeanne A. Powell and Casey Clark*, (Clark Science Center, Smith College, Northampton, MA 01063). Contact Phone: 413-585-3804.

The Smith College Secondary Math and Science Outreach Program works collaboratively with front-line educators to encourage young women students of all abilities, especially underrepresented and underserved minorities, to continue studying math and science throughout high school. The program includes three main components: 1) Twenty-five to thirty teams of math/science teachers and guidance counselors participate in a year-long program which begins with a three-day Current Students/Future Scientists and

Engineers Workshop. This event includes a keynote address, presentations and workshops by successful women in science and engineering, and hands-on laboratory sessions. Each participant receives a stipend and free room and board. Returning to their schools, the teacher-counselor teams implement ongoing plans designed to counteract gender bias in the sciences and to alert female students to the broad range of math, science, and engineering career choices open to them. A follow-up session in the spring allows the teams to present and discuss their year-long activities. 2) TRI-ON, a day of science for 120 ninth- and tenth- grade girls from schools with a large underserved and underrepresented population, is held in early spring. Girls discover the excitement of laboratory investigation and interact with female college science and math majors. 3) Teaching Internships, initiated in 1991, involve ten to fifteen Smith College math and science majors in teaching in public schools. The teaching interns experience the rewards and challenges of classroom teaching, and they also serve as role models for younger students.

47 REVITALIZING SCIENCE IN RURAL NORTH CAROLINA HIGH SCHOOLS WITH TECHNOLOGY, Todd Boyette and Judy Powell* (The Science House, North Carolina State University, P.O. Box 8211, Raleigh, NC 27695-8211). Contact Phone: 919-515-6118.

North Carolina State University oversees two precollege science outreach programs in rural North Carolina: Team Science in chemistry and physics, and the Howard Hughes Science Program in biology, chemistry, and physics. Both programs are collaborative efforts of faculty from several departments in the university. The programs stress incorporating technology in the classroom, supply equipment loans to participants, provide a summer training workshop for teachers, and furnish on-site support from university faculty and staff. The programs are active in fifteen counties in eastern North Carolina and include twenty-eight teacher participants. The programs are primarily funded by grants from the NSF, the Howard Hughes Medical Institute, and the Dreyfus Foundation.

48 PROJECT LIFE – (LABORATORY INVESTIGATIONS AND FIELD EXPERIENCES) AN NSF/LOUISIANA SYSTEMIC INITIATIVES PROJECT, David R. Radford*, College of Education; and Linda L. Ramsey*, College of Life Sciences (Louisiana Tech University, Ruston, LA 71272). Contact Phone: 318-257-4772.

Project LIFE, an in-service program for middle grade teachers of life sciences, focuses on ecology, environmental science, and organismal biology. Project components include an intensive summer course, leadership training, and academic year follow-up through workshops and classroom visits. Teachers are taught by an experienced staff including university scientists, a science educator, and an outstanding middle grades teacher who model a hands-on, learning-cycle style of teaching. Teachers learn science content, process skills, and reform teaching methodology. The course integrates math with science and emphasizes the relationship of science content to the real world. Teachers experience alternative types of assessment including performance-based tasks, journals, concept maps, and questions that promote critical thinking. Participants keep an on-going record of their accomplishments in a Project LIFE portfolio; and receive science supply money from the project and their local system to purchase supplies for classrooms. Project LIFE has trained teachers in Louisiana and Texas and is expanding to other states.

49 SCIENCE TEACHER ENHANCEMENT PROJECT (STEP), Patricia Pierce Ramsey, and Arthur W. Bowman*, (VA HBCU Consortium for Science Education, Hampton University, Hampton, Virginia 23668). Contact Phone: 804-727-5141.

STEP, a National Science Foundation-funded initiative, forms an alliance between the three private Virginia Historically Black Colleges (Hampton University, Virginia Union University, and Saint Paul's College) and nine school divisions, to increase the capabilities of middle school science teachers. Clearly articulated roles of each partner, and the inclusion of all partners in program planning has been invaluable. A unique feature of this project is the careful tailoring of the program to meet the needs of each school division, effected by ongoing communication between all of the partners. The program includes a Lead Teacher and Teacher Trainee component, and emphasizes science content, using a hands-on approach. In addition to science content, the Lead Teachers receive training in leadership, proposal writing, and pedagogical enrichment responsive to the curriculum change directions in science education, especially as it relates to minority and at-risk students. The enrichment is provided by university scientists and educators, through summer institutes and academic year workshops. Results include: use of new technologies in the classroom, cross-grade communication, use of university scientists as presenters for family science programs, and improved knowledge.

50 USING TECHNOLOGY TO PROMOTE SCIENCE AS A BASIC SUBJECT FOR LITERACY: A PRECOLLEGE/COLLEGE/INDUSTRY/GOVERNMENT COLLABORATION, B. L. Redmond* (Microscopy Facility, S.U.N.Y., New Paltz, NY 12561) and A. M. Saturnelli (Newburgh Enlarged City School District, Newburgh Free Academy, 201 Fullerton Ave., Newburgh, NY 12550). Contact Phone: 914-257-3774.

Our goal is to ensure that ALL students have the opportunity to learn science, and it is being accomplished through a unique working model program that: 1) changes the way that teaching and learning take place; 2) incorporates the advanced technology of microscopy directly into the K-12 curriculum; and 3) develops R & D teacher specialists. We conducted three in-service science courses, a Summer Science Microscopy Camp, and a staff development program (the latter funded by a NYS Education Department grant) in which science professors, industrial engineers and scientists interacted with teachers and students to explore the world using high technology. This year, all 5th and 7th graders in the district (200 students) and about 1,000 high school science students are having experiences as active researchers, solving real-life, multi-step problems using all levels of microscopy, including scanning electron and scanning tunneling. Students develop a chronological portfolio, using multimedia formats. Our 1993 Summer Microscopy Camp attendance record was 98%, compared to the typical 75% for other programs.

51 SUMMER INSTITUTE FOR THE TEACHING OF PSYCHOLOGY, Robert F. Rycek* and Richard L. Miller (Department of Psychology, University of Nebraska at Kearney, Kearney, NE 68849). Contact Phone: 308-234-8235.

This presentation will focus on the development of a summer institute to enhance high school and post-secondary teaching in psychology. The purpose of the institute is to provide an intensive teaching seminar in a specific content area of psychology presented by notable researchers and textbook authors in the field. The goal of the institute is to: 1) update participants in a particular content area, 2) introduce participants to new methods and technologies for teaching the content area at the high school and college level, and 3) provide attendees with a set of curriculum materials including classroom exercises and demonstrations which will allow students to conduct scientific experiments in psychology as well as to relate their findings to real world issues. The actual institute is staffed by at least three nationally known experts in a particular topic area of psychology. Over a five-day period, each expert gives at least three major presentations followed by appropriate breakout session which include demonstrations and discussions. The experts supply lecture outlines and supporting materials for their topic area which participants receive as a part of their learning packet. Participants also have the opportunity to share their teaching experiences and expertise.

52 THE NORTH CAROLINA MATHEMATICS AND SCIENCE EDUCATION NETWORK: A COLLABORATION OF UNIVERSITIES AND PUBLIC SCHOOLS, Karen S. D. Shafer*, Science and Math Education Center; Thomas H. Shafer, Department of Biological Sciences, (601 South College Road, University of North Carolina-Wilmington, Wilmington, NC 28403-3297); and Josephine D. Wallace (Math and Science Education Center, University of North Carolina-Charlotte). Contact Phone: 910-395-3168.

The North Carolina Mathematics and Science Education Network, a statewide effort funded through an act of the state legislature, links ten universities with local teachers and students in order to improve content knowledge, pedagogy, and instructional technology. The Network Centers assess the needs of K-12 teachers in their service regions and design relevant short term and long term programs to address these needs. A major advantage of locating these Centers at our state universities is the availability of university faculty as consultants and instructors. Through the coordinated efforts of the Centers at the state level, national funding has been obtained for several major curriculum projects. Statewide network initiatives include TEACH-STAT, a professional development program for elementary teachers focusing on data analysis and statistics in elementary mathematics education, and FIRST (Fund for the Improvement and Reform of Schools and Teaching), a project to improve elementary science and mathematics instruction through peer teacher training. Short courses planned for the UNCW region include animal development, computerized data acquisition, paleontology and mineralogy, DNA biotechnology, and multimedia instruction.

53 EMERITUS SCIENTISTS, MATHEMATICIANS, AND ENGINEERS PROGRAMS, Harold I. Sharlin* (Emeritus Foundation, Emeritus Scientists Program, 1816 Jefferson Place NW, Washington, DC 20036-2571). Contact Phone: 202-296-0254, FAX: 202-785-6697.

The goal of the Emeritus Scientists, Mathematicians, and Engineers (ESME) Program is to introduce elementary school children to the fun and excitement of science and technology. The objective is to use hands-on experiments and demonstrations in the classroom. ESME recruits retired scientists and engineers in the metropolitan Washington, D.C. area. Working with the teachers as a team, the volunteers teach six hour-long classes, then take the children to a laboratory or a museum. Support comes from the D.C. Public School system, and professional societies and corporations. Funding has been provided by the NSF, public, and private foundations. A professional evaluation is conducted every three years.

54 MAGNIFICATION CONCEPTS: THE USE OF VIDEO-PROBE MICROSCOPY TO STIMULATE EXCITEMENT AND HANDS-ON DISCOVERY IN THE SCIENCE CLASSROOM K-12, Cindy Henk[2], Jo Garner[5], James H. Wandersee[4], Marshall Sundberg[1], and Harold Silverman[3]* (Departments of Botany[1], Microbiology[2], and Zoology and Physiology[3], College of Basic Science; Department of Curriculum and Instruction[4], College of Education; Louisiana State University, Baton Rouge, LA 70803; and Westminister Elementary School[5], East Baton Rouge Parish School System, Baton Rouge, LA). Contact Phone: 504-388-4001.

We acquired and loaned several durable, easy-to-use, though expensive video-probe microscopes. This hand-held, automatically focusing instrument can be used by a five year old and provides instant, excellent, in-focus images up to 200X on a video screen visible to all students simultaneously. The teacher is thus freed from the technical and logistic considerations involved in conventional classroom microscopy. K-12 teachers preview our videotape on probe utilization. They assemble and demonstrate the unit in the presence of our personnel, then check out the probe for use in their own classrooms. Extremely enthusiastic students examine samples ranging from their own fingerprints and clothing (on TV!) to pond water, prepared microscope slides, and microscopic polarizing light phenomena. Teachers report heightened interest in conventional microscope use once the "microscopy connection" has been made.

55 THE USE OF OUTREACH WORKSHOPS AND LOAN TRUNKS TO INFUSE MOLECULAR BIOLOGY INTO THE HIGH SCHOOL LABORATORY, Eric Achberger[1], Mary Lou Potter[1], Pat Colbert-Cormier[3], and Harold

Silverman[2]* (Departments of Microbiology[1]; Zoology and Physiology[2], College of Basic Science, Louisiana State University, Baton Rouge, LA 70803; and Lafayette High School[3], Lafayette, LA). Contact Phone: 504-388-4001.

An outreach program was initiated to foster interest in science by introducing high school students to current molecular biological techniques and applications. Hands-on exercises are used to stimulate interest and clarify concepts in molecular biology. The first part of the program is a workshop to familiarize teachers with the equipment, techniques in molecular biology, and student exercises. Teachers that complete the workshop can then borrow the equipment, supplies, and instructions to allow students to do basic experiments in molecular biology. The program is administered by university faculty in biology. There have been three teacher workshops. To date, over 800 high school students (forty-one classes) have used the equipment at twenty high schools.

56 COLLEGE-INDUSTRY ALLIANCES IMPROVING SCIENCE EDUCATION IN KANSAS, Surendra P. Singh*, Jesse Moore, Steve Palubicki, David Shubert, Kent Thomas (Division of Science, Mathematics, and Allied Health, Kansas Newman College, Wichita, KS 67213). Contact Phone: 316-942-4291, ext. 117.

Kansas Newman College's investigative laboratory approach and its partnership with local industries has been motivating precollege students into science since 1990. The Vulcan Chemical Company in Wichita supported our Investigative Summer Science Program for high school juniors where we make science fun and exciting through exploration and testing of ideas, broaden their scientific interests, foster independent scholarship, and with active involvement of community scientists, make them aware of career opportunities and challenges in sciences. Upon completion, 80 to 94% of the participants became interested in pursuing science in college. Our second approach has been to encourage pre-college faculty to have their students present science projects at the annual meeting of Kansas Junior Academy of Science. The Metropolitan Life Foundation has been underwriting all the expenses for promoting participation and hosting of the annual meeting since 1987. The number of science projects/papers has increased from 11 in 1987 to 43 in 1993.

57 THE SCIENCE HOUSE: THE LEARNING OUTREACH PROJECT OF THE COLLEGE OF PHYSICAL AND MATHEMATICAL SCIENCES OF NORTH CAROLINA STATE UNIVERSITY, Michael C. Smith*, David G. Haase (Box 8211, NCSU, Raleigh, NC 27695-8211). Contact Phone: 919-515-6118.

Teaching science is about ideas and doing things. The purpose of the Science House is to increase student enthusiasm for the sciences and to help teachers present challenging and stimulating science and mathematics classes. The Science House emphasizes hands-on laboratory experiences and the partnership of school teachers and university faculty to develop classes and materials for K-12 students. A major goal of the Science House is to provide a model for the interaction between the research university and public schools in providing quality science education for our children. Teacher workshops of the

Science House include *Countertop Chemistry, Physics From the Junk Drawer, Digging Into Earth Science, Hands-On Mathematics, The Science of Astronomy, Integrating Math and Science*, and *Using Computers in the Lab*. Other activities of the Science House include *Physics on the Road* - a traveling physics demonstration program visiting schools around North Carolina, the Imhotep Academy - a Saturday learning experience for students in grades 6-10 with the goal of increasing the pool of African-American students pursuing careers in science and mathematics, the *Howard Hughes Pre-College Science Program* - a program whose purpose is to assist a group of biology, chemistry, and physics teachers in learning new teaching technologies and to develop interdisciplinary teaching modules, and *Team Science* - a program whose purpose is to provide physics and chemistry students in rural high schools the same learning opportunities available to their peers in the metropolitan schools of North Carolina.

58 THE EFFECTS OF MENTORING UPON FIRST YEAR MISSOURI SECONDARY SCIENCE TEACHERS' STAGES OF CONCERN WITH RESPECT TO SCIENCE LABORATORY UTILIZATION, John R. Sode* (155 Home Economics Building, North Dakota State University, Fargo, North Dakota 58105). Contact Phone: 701-237-7103.

This study tested the hypothesis that "There is no statistically significant mentoring variable, or linear combination of mentoring variables, affecting Missouri beginning secondary science teachers' SOC (Stages of Concern) with respect to science laboratory utilization. Demographic data analysis, SOC maximum peak score analysis, item analysis, Pearson r correlation analysis, and factor analysis techniques were applied to data collected from three survey instruments -Science Laboratory Concerns, Mentoring Perceptions, and Demographic-designed for this study. All potential respondents were included in the original mailings. A total of eighty-seven (51.1%) usable responses were obtained. The findings of the study were that four mentoring factors-Professional Assistance, Science Laboratory Assistance, Mentor Availability, and Classroom Instructional Assistance-were used to determine mentoring affects upon Missouri beginning secondary science teachers. Also, the most prevalent stage of concern was Stage 4 (Consequences). This indicated that Missouri beginning secondary science teachers were primarily concerned with the impact of science laboratory utilization upon student learning. Mentoring Factor Four (Classroom Instructional Assistance) was found to be significantly related to Missouri beginning secondary science teachers' stages of concern with respect to science laboratory utilization. Individual mentoring items also were found to be significantly related to science laboratory utilization stages of concern. These relationships were both positive and negative.

59 IMPROVING COLLEGE SCIENCE TEACHING THROUGH PEER COACHING AND CLASSROOM ASSESSMENT, John R. Sode* (155 Home Economics Building, North Dakota State University, Fargo, North Dakota 58105). Contact Phone: 701-237-7103.

Peer coaching involves the observation of one teacher by another. This observation is accompanied by open and honest reflective discussion. The three main components of peer coaching are pre conference (for setting observation guidelines and building trust), observation (the systematic collection of classroom data), and post conference (a non evaluative examination and discussion of the classroom). The non-evaluative post conference involves an examination of the teaching/learning process that occurred during the observation phase. In effective assessment, information on what and how well students are learning is used to make decisions about overall program improvement and to implement continuous classroom improvement. During peer coaching and assessment neither the instructor nor the students are formally evaluated. This session presents a sequential process in which the peer coaching steps of pre conference, observation, and post conference are combined with assessment to provide instructional guidance. An actual case study, using the student complaint, "Lectures are boring and useless," is used to demonstrate the process.

60 RURAL SCIENCE TEACHERS AND NATIONAL CONVENTIONS: A MISSING OPPORTUNITY FOR PROFESSIONAL DEVELOPMENT AND EDUCATIONAL ENHANCEMENT?, John R. Sode* (155 Home Economics Building, North Dakota State University, Fargo, North Dakota 58105). Contact Phone: 701-237-7103.

Rural educators experience unique difficulties in attending national conventions. A program developed at North Dakota State University (NDSU) encourages rural participation. Program goals, participation levels and benefits are examined. On the basis of program evaluations and 1994 program participation levels, the NDSU program appears to stimulate the personal and professional development of elementary and secondary science teachers. Participants were asked to respond to a Likert scale survey instrument with a maximum positive value of 5.0. Survey respondents indicated that elementary and secondary students would benefit (5.0) and that their professional skills had improved (4.7). Respondents also indicated that the 1993 NSTA (National Science Teachers' Association) Convention was a positive experience (4.9), that they would participate in this type of experience again (5.0), and that they would encourage others to participate in this type of experience (5.0). Survey respondents also indicated that this program served a group of educators who were not attending national conventions. Demographic data analysis revealed that nineteen of twenty-five persons responding claimed to have never attended a national convention before. The data analysis also revealed that nineteen of nineteen respondents indicated that the NDSU program enabled them to attend the 1993 NSTA National Convention.

61 THE EFFECTS OF MENTORING UPON FIRST YEAR MISSOURI SECONDARY SCIENCE TEACHERS' PERCEPTIONS OF TEACHING EFFECTIVENESS AND TEACHER RETENTION RATES, John R. Sode* (155 Home Economics Building, North Dakota State University, Fargo, North Dakota 58105). Contact Phone: 701-237-7103.

"How does mentoring affect Missouri beginning secondary science teachers?" A new theoretical paradigm, the Analysis Hierarchy, was constructed to display the relationships amongst five mentoring classes identified from demographic data analysis. Use of the Analysis Hierarchy enabled the formation and testing of null hypotheses examining perceptions of teacher effectiveness, teacher retention, and teacher use of outside assistance. Mentoring was found to positively affect Missouri beginning secondary science teachers' perceptions of their teaching effectiveness regarding science labs. This effect was significant between content (93.9% of class) and non-content (69.9% of class) mentored teachers. Mentoring was found to positively affect Missouri beginning secondary science teachers' intentions to continue teaching. This effect was significant between mentored (89.3% of class) and nonmentored (64.5% of class) teachers. Mentoring was not found to affect the intentions of Missouri beginning secondary science teachers to seek professional assistance outside the mentoring relationship. Demographic trends, indicated content (54.5% of class) and noncontent (69.6% of class) teachers did diverge on this variable.

62 SUMMER ENRICHMENT PARTNERSHIP (SEP)—SOCIETY OF HISPANIC PROFESSIONAL ENGINEERS (SHPE), Charles E. Vela* (Society of Hispanic Professional Engineers, 8116 Paisley Place, Potomac, MD 20854). Contact Phone: 703-883-6808.

SEP recruits talented Hispanic high school students in the Washington metropolitan area and seeks to increase the number of Hispanics who enter graduate programs in engineering and science. New students are exposed to engineering, experimental science and business, and visit R&D centers and corporations. Returning students take college level courses, such as Vector-Based Analytic Geometry and Probability and Statistics. Advanced students work on special projects. Hispanic engineers, scientists, and managers offer career guidance. Parental participation is actively encouraged. Students are selected based on: a) commitment to succeed, b) academic record, and c) willingness to attend the program through graduation. Courses are taught by university faculty, with one teacher assistant per five students. Program evaluation encompasses: 1) student participation and performance, 2) school achievement, and 3) continuation to college. SEP is a partnership between the Society of Hispanic Professional Engineers, The Catholic University of America, NASA, school districts, parents and students, and Hispanic professionals.

63 A PARTNERSHIP BETWEEN BIOLOGIC/BIOMEDICAL RESEARCH SCIENTISTS AND PRECOLLEGE EDUCATORS, Norman P. Willett*, Temple University School of Medicine, Philadelphia, PA 19140). Contact Phone: 215-221-4905, FAX: 215-221-7788.

A model program has been developed to provide a mechanism for precollege educators to interact with university faculty who are working scientists. Components of the program included an in-depth laboratory experience which involved pairing active research faculty in the biomedical sciences with the educators for a seven week period during the summer; a supportive curriculum in the biomedical sciences to enhance and enrich the laboratory experience; construction of a teaching module by the educators which can be brought back to their schools to improve their science education programs; and development of means of disseminating the modules at the local, regional, and national levels. Excellent modules were developed by the teachers in a wide variety of disciplines. Formative evaluation of the program by the teachers indicated a very high degree of enthusiasm for all aspects of the program. This model will support the development of programs that join working scientists and precollege educators in enhancing science education in the biomedical sciences. It will have a multiplier effect far beyond the participants, impacting on fellow educators, students considering careers in the sciences, and the lay public.

64 PRODUCTS, PROCESSES AND TECHNOLOGY IN THE ELEMENTARY SCHOOL CURRICULUM, Velda Goldberg and Sandra Williams* (Biology Department, 300 The Fenway, Simmons College, Boston, MA 02115). Contact Phone: 617-521-2664.

This project is designed to improve science education at the elementary school level by facilitating collaborative efforts among teachers, science coordinators, principals, and representatives of local industries. The project is funded by the National Science Foundation and six Boston-area companies. In conjunction with these companies, we developed six sample modules which provide students with concrete examples of products, processes, and technologies that demonstrate scientific principles found in the elementary school science curriculum. These sample modules include "Treating Vascular Disease" with Boston Scientific Corporation, "Decision-Making Processes" with Clearpoint Corporation, "Patterns in Miniature" with Digital Equipment Corporation, "Inventing the Pen" with the Gillette Company, and "Fiber Optics Communication" with Peter Fuller Oldsmobile, Inc. One hundred participants worked with these sample modules during summer workshops and then, using them as guides, developed their own modules with businesses and industries in their communities.

65 WHALENET/ENVIRONET, J. Michael Williamson*, Assistant Professor (Science Department, Wheelock College, 200 Riverway, Boston, MA 02215). Contact Phone: 617-734-5200, ext. 256;
e-mail: mwilliamson@vmsvax.simmons.edu.

WhaleNet has established a network where students, educators, and scientists can interact and share data for use in interdisciplinary curricular and student research activities in classrooms around the world by utilizing telecommunication. This program enables students to participate in marine/whale research programs in real-time with WhaleNet data and supplementary curriculum materials regardless of their geographic location. Systems have been established with research organizations and whale watch companies whereby research data is posted by scientists and students participating in whale watches on the WhaleNet bulletin board and shared with participating classrooms. WhaleNet presently has contacts with classrooms across the nation, and with research groups, whale watch organizations, science museums, and universities from Alaska to North Carolina, Hawaii to Maine, and Belize to Norway. WhaleNet has plans to make existing whale and fisheries research databases available for classroom use and to have research data from satellite tagging programs on various species of whales available for classroom access in real-time.

66 DESCRIPTION OF AN S-T-S AUTHENTIC LEARNING CURRICULUM, Kevin C. Wise* and Gerry Saunders (Science and Environmental Education, Department of Curriculum and Instruction, Southern Illinois University, Carbondale, IL 62901). Contact Phone: 618-453-4214.

This poster outlines the components of an authentic learning curriculum that deals with Science/Technology/Society (S-T-S) issues. The program is formally known as "Investigating and evaluating STS Issues and Solutions." The major components of this curriculum include: 1) defining S-T-S issues, 2) analyzing issues, 3) starting issue investigation, 4) collecting primary data on S-T-S issues, 5) interpreting data from issue investigations, and 6) planning to resolve S-T-S issues. The program has been extensively tested and used in various forms with elementary, middle, and high school students, as well as in teacher training programs. Research on the effects of using this approach to train students to deal with S-T-S issues suggests that it promotes in-depth issue investigation skills and responsible citizenship behavior.

67 SCIENCE FOR PHYSICALLY AND MENTALLY CHALLENGED STUDENTS, Lynn Whalen* (SMI Consulting, Inc., 1 Pamela Court, Williston, VT 05495). Contact Phone: 802-878-2928.

Science is all around us in everything we do, but science education is not always provided to youngsters who are physically and mentally challenged. The problem is not that most children can't learn, it is that we are not explaining or modeling to meet each child's needs. We must rethink our ways of teaching and enthusing. Science can be taught to, and enjoyed by, challenged youth to explain the world around them. The sciences should be friendly. Scientific vocabulary can be intimidating and everyday words must be used. Increased tactile and visualization methods based on social concepts and sign language can be used to improve science education for physically and mentally challenged students.

68 JOURNEYS INTO THE MICROCOSMOS: A CREATIVE COLLECTIVE BUILDS NEW VEHICLES FOR SCIENCE EDUCATION REFORM, Douglas Zook, Director; Pam Pelletier*, Assistant Director (Microcosmos, School of Education, Boston University, 605 Commonwealth Avenue, Boston, MA 02215). Contact Phone: 617-353-2754, FAX: 617-353-4170.

Microcosmos is a university-centered curriculum development, teacher training effort that centers around a volunteer-based collective made up of teachers, scientists, artists, graduate students, and curriculum developers. Initiated on a zero funds, grassroots level six years ago, but currently funded in part by the National Science Foundation, program objectives include stimulating new enthusiasm for science in the precollege classroom through explorations of "inner space"; bringing a new connection of students to the planet through the discovery of the dominant roles of microbial life in earth systems; and modeling, methods of instruction based upon constructivist approaches and a learning cycle which emphasizes ongoing student creation of their learning environment. Ongoing assessment suggests that Microcosmos with its divers, community-based Team, could serve as a potential model for other, future university-based science education reform efforts.

69 A WORLD IN MOTION, John A. Boynton* (SAE, 400 Commonwealth Drive, Warrendale, PA 15096), William G. Agnew (3450 Thirty-One Mile Road, Washington, MI 48096). Contact Phone: 412-776-4841.

A World in Motion is a physical science curriculum supplement for grades four, five, and six which responds to the need to promote and teach sound science and mathematics concepts. Using the A World in Motion kits, teachers work in partnership with practicing engineer or scientists volunteers to provide students with fun, exciting, and relevant hands-on science and math experiences. During the A World in Motion experience, students work together in "Engineering Design Teams" exploring physics concepts through a series of activities. Each student is assigned a role as either a facilities engineer, development engineer, test engineer, or project engineer and is given responsibilities paralleling those of engineers in industry. The program culminates in a "Design Review" where students can communicate their results, demonstrate their designs, and receive recognition for their efforts. They are given a chance to take on responsibility and build self-esteem. Since January 1991, over 12,000 volunteer engineers have been involved with the program, with a distribution of 20,000 A World in Motion kits throughout the U.S. and Canada.

70 PROJECT ASTRO: ASTRONOMERS AND TEACHERS AS PARTNERS IN THE CLASSROOM, Andrew Fraknoi, Principal Investigator; and Jessica Richter* (Project ASTRO, Astronomical Society of the Pacific 390 Ashton Ave., San Francisco, CA 94112). Contact Phone: 415-337-1100, FAX: 415-337-5205.

Project ASTRO is an innovative pilot program to support science education in California schools by linking teachers and students in grades four-nine with amateur and professional astronomers. Funded by the National Science Foundation, Project ASTRO's goals are to support ongoing partnerships between teachers and astronomers and to involve students in hands-on astronomy activities. The two-year pilot project started in spring 1993 and has four phases: 1) evaluating existing astronomy education materials; 2) recruiting, matching, and training teachers and astronomers; 3) providing assistance and support to teacher/astronomer teams and assessing the effectiveness of the partnerships; and 4) developing two publications, *The Universe at Your Fingertips: A Resource Notebook for Teaching Astronomy* and a *Project ASTRO How-to Manual*. A total of forty-five teams of astronomers and teachers in a range of school settings are participating in the project. Partners are provided with materials, resources, guidelines, and support and are encouraged to develop their program based on local needs and interests. Visiting astronomers lead hands-on activities, give talks, organize evening star parties, arrange field trips, serve as role models and mentors to students, and assist with curriculum development and planning. Preliminary findings indicate that most teachers and astronomers are highly positive about Project ASTRO. The training and materials given to participants have contributed significantly to project success so far. The largest barrier to effective partnerships appears to be time for planning and classroom visits. Currently, Project ASTRO is investigating expansion to other communities around the country.

71 ORNL/NSF ELEMENTARY SCIENCE LEADERSHIP INSTITUTE, Terry L. Lashley* (ORNL, P.O. Box 2008, 105 MIT, MS 6496, Oak Ridge, TN 37830). Contact Phone: 615-574-0689.

Begun as a Teacher Enhancement Project in 1990, Oak Ridge National Laboratory (ORNL) is now hosting an annual four-week Elementary Science Leadership summer institute for twenty-five teacher/administrator participants. During 1993-95 summer institutes, the participants receive instruction in science/math content, pedagogy, leadership training, and evaluation techniques. Science topics and instruction will be selected from the best available resources at ORNL, pedagogy and evaluation techniques will be directed by the University of Tennessee's College of Education, and leadership training will be based on established leadership training models. During the academic year component, participants will: 1) share new math/science knowledge and curriculum with their students and fellow teachers while continuing to develop additional curriculum to share with other Leadership Institute participants, 2) work with the established state-wide advisory group to contribute to systemic reform in math/science education, and 3) prepare and deliver NSF leadership Institute-related math/science presentations at local and state educational conferences. Graduate credit for summer and academic-year participation in the NSF Leadership Institute will be offered through the University of Tennessee at Knoxville.

72 OAK RIDGE NATIONAL LABORATORY'S (ORNL) ECOLOGICAL AND PHYSICAL SCIENCES STUDY CENTER: A HANDS-ON SCIENCE PROGRAM FOR K-12 STUDENTS, Sandra P. Bradshaw* (ORNL, P.O. Box 2008, 105 MIT, MS 6496, Oak Ridge, TN 37830). Contact Phone: 615-241-3653.

In our tenth year of educational service and outreach, Oak Ridge National Laboratory's Ecological and Physical Sciences Study Center (EPSSC) provides hands-on, inquiry-based science activities for area students and teachers. Established in 1984, the EPSSC now hosts over 20,000 student visits. Designed to foster a positive attitude towards science, each unit includes activities which reinforce the science concept being explored. Outdoor science units provide field experience at the Department of Energy's Oak Ridge National Environmental Research Park and outreach programs are offered on-site in area schools. Other programs are offered as extensions of the EPSSC core programs, including on-site student science camps, all-girl programs, outreach science camps, student competitions, teacher in-service presentations and teacher workshops.

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